

REMARKS

The following remarks refer to the Examiner's comments on the noted page and line number of the Office Action letter dated 4-18-01. His comments are quoted here for convenience. Where Remarks refer to pages in the Specification, the reference is made to the "Marked-up Version".

Quoting p. 2, beginning line 20:

"The Specification is objected to under 35 U.S.C. 112, first paragraph, as failing to provide as adequate written description of the invention and as failing to adequately teach how to make and/or use the invention i.e. failing to provide an enabling disclosure."

Remark 1:

The specification has been revised to clarify all points made by the Examiner. Descriptive material and distinctions between the present invention and prior art have been added in the appropriate areas of the Specification. Several examples are noted here: (1) the "Host Metal Selection" section on page 10 is expanded; (2) the enabling process is clarified in Specification sections "Brief Summary of the Invention" on page 4 and "How the Reactor Works" on page 9; (3) the operating range of the reactor in terms of deuterium chemical potential, temperature and pressure is now shown in the text and in the Drawings, Figure 7,; and (4) in the claims, the methods for enabling and controlling the fusion reaction are now claimed.

Quoting p. 3, beginning line 1:

"There is no reputable evidence of record to support any allegations or claims that the invention involves nuclear fusion nor, that any allegations or claims of "excess heat" are valid and reproducible,....."

Remark 2:

The Examiner's statements are based on newspaper articles, interviews and technical reports that were published many years ago. While these articles and reports are of historical interest, they do not reflect the current status of tests that

1 demonstrate that deuterium fusion and the resulting "excess heat" is indeed taking
2 place when the 'F&P effect' is initiated and sustained in the deuterium-palladium
3 system.

4 Of the many successful cold fusion experiments that have been conducted
5 worldwide in the past 10 years (see **Enclosures 2 & 3**), four such experiments of
6 particular significance have been replicated in the laboratories of the Stanford
7 Research Institute, International, (SRI) in Menlo Park, CA.

8 The four original experiments were conducted by: (1) Dr. Arata, in Japan using
9 a combination of electrolytic and gas loading of the deuterium into the palladium host;
10 (2) Dr. Miles, in California using electrolytic loading; (3) Dr. Case, in Connecticut,
11 using pure gas loading in the presence of carbon; and (4) Dr. McKubre, in California,
12 using electrolytic loading. The original experiments clearly produced excess heat as
13 well as the expected helium byproducts of the fusion reaction. (See references cited
14 in Enclosure 1.)

15 The replication effort at SRI was conducted with remarkable attention paid to
16 accuracy of heat measurements and to laboratory techniques that preclude any
17 possibility of contamination from external sources. The presence of helium 4, helium
18 3 and tritium was not only detected but measured and correlated to the excess heat
19 produced. This meticulous work, under the direction of Dr. Michael McKubre with
20 participation by Dr. Peter Hagelstein of MIT, was made possible by a ten-year series
21 of improvements in both laboratory techniques and advancements in mass
22 spectrography demanded by a skeptical scientific community. It is the opinion of the
23 applicants that, as the process of critical review by the scientific community
24 progresses, one can no longer dismiss the reality of deuterium fusion and the
25 production of heat in the deuterium-palladium system.

26 The results of this experimental replication work were presented at ICCF-8, the
27 8th International Conference on Cold Fusion held in Italy during the early part of the
28 year 2000 and are just now published in the proceedings of that conference. A copy
29 of the paper prepared and presented by Dr. Michael McKubre, et al, is included as
30 **Enclosure 1** and is incorporated into the Specification as **Reference 6**.

31 *This noted group of experiments and their replication at SRI constitutes*
32 *reputable evidence that nuclear fusion and excess heat can be induced in the*
33

1 *deuterium-palladium system and that the effect is reproducible.*

2

3 **(Note: Remark #3 is not used.)**

4

5 **Quoting p. 3, beginning line 1:**

6 "There is no reputable evidence , nor that the invention as
7 disclosed is capable of operating as indicated and capable of providing a useful
8 output."

9 In response to the examiner's comment quoted above, **Remarks 4 thru 8**
10 must be considered as a group:

11

12 **Remark 4: Useful output**

13 For the output of any deuterium-palladium system to be considered useful for
14 commercial applications, the output power density must be in excess of 1000 watts
15 per cubic centimeter of palladium for the heat produced to be cost competitive with
16 that produced by fossil fuels due to the high cost of the host metal. Further, the
17 reactor must not rely on the continuous application of expensive energy input to
18 achieve an 'excess'. This definition of 'useful power' precludes the use of any
19 deuterium loading method other than 'gas loading'.

20 The invention set forth herein is a pure gas loaded reactor. The design of the
21 reactor and the operating procedures set forth in the Specification will produce the
22 necessary conditions for achieving power densities in the commercially useful range.
23

24 **Remark 5: Experimental evidence of high density heat.**

25 Experimental evidence of high power densities being produced by the
26 deuterium-palladium system is found in some of the early work performed by
27 Fleischmann & Pons (F&P). While the vast majority of their work was performed
28 using a carefully controlled electrolytic process, they experienced extremely high
29 power densities when a cell electrolyzing a 1 cubic centimeter sample of palladium
30 accidentally ran dry due to electrolyte boiloff. This stopped the electrolytic process
31 and the Pd cathode began to operate as a 'gas loaded' reactor.

32 When immersed in the liquid electrolyte, the heat transfer coefficient from the Pd
33

1 cube to the liquid was very high. When the electrolyte 'boiled off', the electrolytic
2 process stopped and the heat transfer coefficient from the Pd to the surrounding air
3 dropped to a very low value. The relatively small amount of fusion heat being
4 generated in the sample (estimated to be about 100 watts/cc at 100°C) was greater
5 than that which could be transferred to the surrounding atmosphere because of the
6 reduced heat transfer coefficient. As a result, the palladium experienced positive
7 temperature feedback. The temperature began to rise and the reaction rate began to
8 increase rapidly. The 1 cc sample of Pd reached its melting temperature of 1554°C.
9 A portion of the Pd cube actually vaporized (at 2963°C) before the episode eventually
10 came to an end. The lengthy overnight episode ended when the last of the ionic
11 deuterium in the Pd sample was diffused out to the lab atmosphere and the reacting
12 deuterium was converted to the helium and tritium byproducts of the fusion reaction.
13 The melting and vaporizing of the palladium is clear evidence of a very high power
14 density. The large hole in the laboratory bench and the large depression in the
15 concrete floor due to vaporization of those materials is additional evidence of
16 extremely high power densities. (See **Enclosures 4 & 7.**) *Based on even the most*
17 *conservative estimates of the energy that must have come from that 1 cc of palladium,*
18 *there can be little doubt that a nuclear 'event' took place in the F&P lab at very high*
19 *temperatures producing commercially useful levels of heat.*

20 Following this near disaster, F&P conducted a number of controlled 'boil dry'
21 experiments using Pd rod instead of a cube. These experiments produced power
22 densities in the range of 3.6 kw/cc of Pd at temperatures estimated to be in the 500 to
23 600°C range. No effort was ever made by F&P to maintain a deuterium atmosphere
24 at the surface of the palladium after boiling dry, so the high density fusion reaction
25 came to an end in due time.

26 *The experimental evidence developed by F&P is now incorporated into the*
27 *amended Specification in Figure 9 of the "Drawings" section. This Figure 9 also*
28 *shows other data at temperatures above room temperature showing the strong*
29 *influence of higher temperatures on the power density.*

30 F&P did not pursue gas loading as a method for producing high density heat
31 from deuterium fusion because they, as well as all other skilled artisans, believed that
32 the key to enabling the fusion process was to achieve very high deuterium

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1 concentrations in the palladium metal. While they correctly envisioned no practical
2 way to achieve high D/Pd loading ratios by gas loading methods due to the extreme
3 pressures required *at low temperatures* (100,000 atmospheres and higher), they
4 failed to recognize that the D/Pd concentrations in the 'boiled dry' cathodes were
5 indeed quite low when the palladium was producing the highest power densities. As
6 were all others skilled in the art of electrolysis, they were victimized by the kind of data
7 shown in Figure 2 of **Enclosure 5** and the 'logical' conclusions one might draw.

8 *The invention disclosed herein relies on reproducing and maintaining the very*
9 *high 'system free energy states' at the high temperatures and modest equivalent*
10 *pressures that were present when the 'boiled dry' reactors were producing power*
11 *densities in the commercially viable range.*

12

13 **Remarks 6: Operating zone for high density heat.**

14 To determine if it is practical to design a gas loaded reactor capable of
15 producing high power densities, it is necessary to determine the D chemical
16 potentials produced by electrolysis at typical operating temperatures when producing
17 low density excess heat. The technique for making these estimates is described in
18 **Enclosure 10** using the TCP Equilibrium Diagram. The results are presented in
19 Figure (5) , **Enclosure 5**, "This Invention vs Prior Art". At typical electrolyte
20 temperatures, on the left side of the chart, the equivalent free energy states
21 (expressed as the D Gas Chemical Potential) produced by electrolysis range below
22 15 kJ/mol. (Higher values are not possible due to the temperature limit on the
23 electrolyte and due to the vagaries of the electrolytic process.) It is known that the
24 presence of an electric field does work on the dissolved deuterium and may have the
25 effect of producing an additional increment to the deuterium chemical potential; this
26 increment has been estimated to be less than 5 kJ/mol. To produce substantially
27 higher density power by gas loading, it is necessary to produce D gas chemical
28 potentials substantially higher than those associated with the low power densities of
29 the electrolytic process.

30 On the right side of Figure 4, **Enclosure 5**, the broad operating zone for this
31 present invention is noted between 400°C and more than 1400°C and pressures from
32 more than 4000 atmospheres to 25 atmospheres or so (noting that pressures must be
33

1 reduced at the higher temperatures due to reduced strength properties of typical
2 reactor pressure vessel materials at temperatures above 500°C to 700°C).

3 *The reactor design disclosed herein is capable of producing D gas chemical*
4 *potentials twice that produced by any known prior art; gas loading or electrolysis.*

5

6 **Remark 7: A change of thermodynamic state is the key to operability.**

7 Thermodynamics teaches us that a 'change of state' will occur in a system if
8 and when a lower free energy can be achieved. This is analogous to the solid-liquid-
9 vapor state changes for most materials when the required combination of temperature
10 and pressure are produced. In solid state physics, when substances are dissolved in
11 metals (such as hydrogen in palladium) the 'free' electrons change to a delocalized
12 state or to a multiplicity of smaller wave functions having the symmetry of the metal
13 lattice (sometimes referred to as the 'Fermi sea', or the 'Fermi gas').

14 While the exact nature of the deuterium change of state is not yet explained to
15 the satisfaction of the technical community, the reality of deuterium fusion in the
16 palladium lattice (**Remark 2**) leads to the conclusion that a state change does
17 indeed take place to enable the reaction and to be consistent with thermodynamics.
18 In **Enclosure 8**, such a change of state is described in layman's terms as taken from
19 one of today's prominent theories.

20

21 **Remark 8: Operability**

22 Determination of the system free energy state at the threshold of the necessary
23 'change of state', for the selected host material, and operation of the system at free
24 energy states higher than the threshold are key to making this invention operable
25 over the broad range of operating conditions now noted in Figure 7 of the revised
26 Specification.

27

28 **Quoting p. 3, beginning line 5:**

29 "The invention (see for example pages 1+ of the specification) is
30 considered as being based on the "cold fusion" concept set forth by
31 Fleischmann and Pons (hereafter F and P) (see the 3/24/89 article by D.
32 Braaten). This concept relies on the incorporation of deuterium into a metal
33 lattice. While F and P relied on electrolysis of heavy water to incorporate
deuterium into the metal lattice, it was also known that as a variation, the
deuterium could be incorporated into the metal lattice by bringing the metal in

1 contact with deuterium gas.

2 "Thus It is clear that applicant's invention is just a variation of the cold
3 fusion concept set forth by F and P."

4 **Remark 9:**

5 As observed by the examiner, the invention disclosed herein incorporates
6 deuterium into the metal lattice by bringing it in contact with the surface of the metal
7 under specific conditions. When deuterium gas and the host metal are brought
8 together inside of a pressure vessel, equilibrium conditions between the deuterium
9 gas subsystem and the deuterium-metal subsystem are noted on the D-Pd TCP
10 Equilibrium Diagram now shown in Figure 8, of the revised Specification. The
11 definition of equilibrium in this gas-metal system is that the chemical potential of the
12 deuterium gas in the gas sub-system is equal to the chemical potential of the
13 dissolved deuterium in the metal sub-system. The data incorporated in the
14 Equilibrium Diagram are a composite of fragmentary data presented in the literature
15 over a period of more than 100 years. (See TN-1.0 in **Enclosure 9**.)

16 The present inventors make no claim that bringing the deuterium gas in contact
17 with the surface of the metal is a unique method of incorporating deuterium in the
18 metal. Further, they make no claim as to the invention of the "cold fusion concept".

19 *What is claimed is the system and methods for enabling and accelerating the*
20 *fusion reaction making the present invention easily distinguished from all prior art.*

21
22 **Quoting p. 3, beginning line 13:**

23 "However, as set forth more fully below, this "cold fusion" is still no more
24 that just an unproven concept.

25 "Subsequent to the announcement of the cold fusion concept by F and
26 P, many laboratories have attempted to confirm the results of F and P.

27 "The results of these attempts at confirmation were primarily negative
28 and even of the few initial positive results, these were generally retracted or
29 shown to be in error by subsequent experimenters (see for example, the article
30 by Stipp in the Wall Street Journal and the article by Browne in the New York
31 Times (particularly page A22))"

32
33 **Remark 10:**

34 While Browne touts the sensitive equipment used by Cal Tech, their work later
35 turned out to be less than totally professional.

36 Since the noted articles by Stipp and Browne were published, numerous

1 experiments have been conducted at various laboratories around the world that
2 clearly show excess heat plus the production of helium byproducts. Four of these
3 critical experiments have been replicated recently by a reputable and prestigious
4 laboratory (SRI) according to the normal protocol of scientific discovery. (See
5 **Remarks 2** above, **Reference 6** in the revised Specification and in **Enclosure 1.**)
6 *The articles cited in the Office Action are of historical interest only. We can no*
7 *longer considered 'Cold fusion' just an unproven concept.*

8

9 **Quoting p. 4, beginning line 1:**

10 "The general consensus by those skilled in the art and working at these
11 various laboratories is that the assertions by F and P were based on
12 experimental errors, (e.g. see The New York Times article by Browne, Kreysa et
13 al, Lewis et al, Hilts, Horanyi, Ohashi et al, MisKelly et al, and Chapline).

14 **Remark 10a:**

15 The Browne article reports the scorn placed on F&P by many of their peers
16 'skilled in the art'. It was discovered later by review of their data, that some of those
17 who scorned the loudest had themselves conducted terribly flawed attempts at
18 replicating the F&P effect; some actually having produced excess heat and didn't
19 recognize it. Today, the most careful and better equipped labs in the U.S., Japan and
20 Italy have produced excess heat along with the expected helium byproducts.

21

22 **Remark 10b:**

23 The reports by Kreysa, et al, Lewis, et al, Hilts, Horanyi, Ohashi, et al, and
24 MisKelly, et al, cite their failures to replicate F&P's work and concluded that F&P had
25 to have made experimental errors. Such reports are of historical interest since the
26 reality of deuterium fusion in palladium is now established. It would, however, open
27 up the question as to who actually failed to create the necessary critical enabling
28 conditions or who may have actually made experimental errors.

29

30 **Remark 10c:**

31 The Chapline article speculates that the deuterium gas pressures required to
32 produce a "pyconuclear" reaction would be on the order of 10 million atmospheres.
33 The applicant's invention produces free energy states at elevated temperatures which

1 have equivalent room temperature pressures in this same range and higher.

2 **Chapline** also notes that apparently the dissolved deuterium behaves in a
3 manner similar to that of the free electrons in their delocalized state. He sees this as
4 amusing rather than a real possibility. Doctors Talbot and Scott Chubb who have
5 developed one of the leading solid state deuterium fusion theories based on the
6 concept of the dissolved deuterium becoming delocalized, just as the free electrons
7 do, to nullify the Coulomb repulsion forces (see **Enclosure 8**). (The Chubbs' theory
8 is one that fits the experimental data and is consistent with the teachings of
9 thermodynamics and solid state physics.)

10 **Chapline** makes no mention of attempts on his own to replicate the F&P work at
11 the Livermore National Laboratories.

12 As to the reality of deuterium fusion in the D-Pd system in today's light, please
13 revisit **Remark 2** and **Enclosure 1**.)

14

15 **Quoting p. 4, beginning line 5:**

16 "It is also the general consensus by those skilled in the art and working
17 at these various laboratories that there is no reputable evidence of neutron,
18 gamma ray, tritium or helium production to support the allegation or claim that
19 nuclear fusion is taking place, nor is there any reputable evidence to support
20 the allegation or claim of excess heat production. See for example (In addition
21 to the above listed references), pages A14 of the 7/13/89 edition of the
22 Washington Post, Cooke, Alber et al, Faller et al, Cribler et al, Hadjas et al, Shani
23 et al, Ziegler et al, Price et al, Schrieder et al, and page A3 of the 3/29/90
24 edition of the Washington Post."

22

23 **Remark 10d:**

24 The **Washington Post** article cites the end of government funding for any "cold
25 fusion" work based on the Energy Research Advisory Board's recommendation.

26 **Cooke's** document is a trip report of a side conversation with Harwell people who had
27 recently experienced failure to replicate F&P's work or the gas loaded Frascatti-type
28 experiments. **Horanyi** argues about the vagaries of electrochemistry and takes issue
29 with F&P statements. **Faller** could not measure gamma rays however he did measure
30 tritium in an amount equal to 1/3 of that reported by F&P. **Cribler** could find none of
31 the expected radiation had fusion taken place. **Hadjas** added to the list of
32 experimenters that failed to measure neutrons in Frascatti-type gas loading

33

1 experiments (see **Remark 12**). **Shani** measured neutron bursts but speculated that
2 they may have been triggered by an outside source rather than deuterium fusion.
3 **Ziegler** and **Schrieder** both failed to replicate F&P's work. **Price** failed to measure
4 charged particle emissions from deuterated samples of Pd and Ti. In the cited
5 **Washington Post** article, **Salamon** and **Price** depreciate F&P in light of their own
6 failure to replicate the latter's work.

7 *None of these articles and reports reflect on the efficacy of this present*
8 *invention.*

9 Many of those 'skilled in the art' conducted terribly flawed attempts at replicating
10 the F&P effect. An error common to most electrolytic experiments was that no
11 measurements of the actual loading ratio (D/Pd) were made leaving doubt that their
12 failed replication efforts were valid. The SRI labs in Palo Alto found it absolutely
13 necessary to establish this assurance that loading actually took place in every
14 instance and their success record exemplifies their care.

15 In any case, and in today's light, using advanced testing and measuring
16 techniques, the production of excess heat and the expected helium byproducts has
17 been confirmed. (See **Remark 2** and **Enclosure 1**.)

18

19 **Quoting p. 4, beginning line 15:**

20 "Note that the negative teachings of the gaseous systems of such
21 references as **Friedmann et al**, **Price et al**, **McCracken et al**, and **Badurek et al**,
22 are particularly pertinent in regard to showing inoperability of applicants
23 gaseous system."

24 **Remark 11:**

25 The cited report by **Friedmann, et al**, concerns, in part, gas loading experiments
26 using Titanium as the host metal. **Friedmann** followed **De Ninno's** procedures and
27 went to great lengths to achieve high loading ratios by temperature cycling his Ti and
28 TiFe samples repeatedly from liquid nitrogen temperature to 200 deg C. This
29 procedure is applicable to the process for storing hydrogen in titanium (i.e. packing in
30 the maximum amount of gas by achieving high D/Pd loading ratios) but is well known
31 to have a very destructive effect on the uniformity of the metal's lattice structure.
32 Since the leading solid state fusion theories of today involve coherent action within
33 the lattice structure to nullify the Coulomb repulsion forces (see **Enclosure 8**), the

1 integrity of the lattice must be preserved to allow the fusion process to be enabled.
2 One would not expect to produce nuclear fusion using the gas loading testing
3 techniques employed by **Friedmann** and De Ninno. It is surprising to the present
4 inventors that De Ninno achieved positive results. (Also see **Remark 26b.**)

5 Also, the maximum deuterium gas chemical potential (i.e. the measure of the
6 system free energy state) achieved in Friedmann's work was very low (7.7 kJ/mol)
7 and *would not be expected (by the present inventors) to enable the fusion reaction*
8 *had it been applied to a palladium system.* This failed approach by Friedmann does
9 not reflect on the efficacy of the approach employed in the present invention. The
10 threshold chemical potentials for a gas loaded palladium system are, in most cases,
11 in excess of 20 kJ/mol. (The threshold deuterium gas chemical potentials required to
12 enable a fusion reaction in titanium has not yet been determined by the present
13 inventors.)

14

15 **Remark 12:**

16 The cited report by **Price, et al**, concerns, in part, gas loading experiments using
17 both titanium and palladium as the host metals. **Price** used a similar temperature
18 cycling technique prior to final loading that **Friedmann** and De Ninno used. The
19 primary difference is that the deuterium gas chemical potential used during the
20 measurement runs was even lower than Friedmann's (<1kJ/mol). (Also see **Remark**
21 **26b.**)

22

23 **Remark 13:**

24 The cited report by **McCracken, et al**, again, is similar to the **Price, Friedmann**
25 and De Ninno works, but excluding palladium as a host metal. Here they produced
26 deuterium gas chemical potentials in the range of <1 kJ/mol to 6.0 kJ/mol which are
27 well below the minimum required to enable the fusion reaction.

28

29 **Remark 14:**

30 The cited report by **Badurek, et al**, again is similar to the **Price, Friedmann,**
31 **McCracken** and De Ninno work where titanium was gas loaded and temperature
32 cycled, also citing the pulverization of the outer surface of titanium. The actual

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1 deuterium test pressure is not reported to permit a chemical potential calculation, but
2 it may be assumed that the deuterium gas chemical potentials were in the same very
3 low range as in the other experiments since Badurek made no mention of using an
4 ultra high pressure test apparatus.

5

6 **Remark 15:**

7 Note that the four papers, cited above, report failed attempts to replicate work
8 carried out by the Frascati Group which is covered by European Patent 0394204 by
9 Scaramuzzi, De Ninno, et al. All gaseous experiments aimed at achieving high D/Pd
10 loading ratios are essentially a waste of time, as so aptly reported, because it is not
11 practical to achieve the ultra high pressures needed to produce the threshold free
12 energy state (D chemical potential) at the low temperatures. (See **Enclosure 5**.)

13 *The failed approach noted in the four cited papers and in the Scaramuzzi*
14 *patent does not reflect on the efficacy of the present invention.*

15

16 **Quoting p. 4, beginning line 15:**

17 "Of particular interest is page A3 of the 3/29/90 edition of The
18 Washington Post (which refers to the negative findings of a physicist who
19 tested Pons' own cold fusion apparatus, for nuclear output (for a more complete
20 analysis of said "negative findings", note the article by Salamon et al)). Also of
21 interest in this respect is the Cooke reference which on pages 4 and 5, refers
22 to the attempts at Harwell to obtain "cold fusion" and that Fleischmann (of F and
P) had requested help from Harwell in verifying the cold fusion claims. Note
that said page 5 also indicates that data was collected in Frascati-type
experiments (i.e. gaseous).

23 "The last paragraph on said page 5 states:

24 "After three months of around-the-clock work at a cost of a half
25 million dollars, the project was terminated on June 15. This program was
26 believed to be on of the most comprehensive worldwide with as many as
27 30 cells operating at a time and over 100 different experiments
performed. The final result of this monumental effort in the words of the
official press release was, "In none of these experiments was there any
evidence of fusion taking place under electrochemical conditions". It
should also be added that there was no evidence of excess heat
generated by any of the cells."

29

30 **Remark 16:**

31 As noted in **Remark 2**, the search for cold nuclear fusion has persisted to the
32 present time (see **Enclosures 2 & 3**). Since early days covered by the obsolete

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1 articles cited above, critical experiments showing excess heat and nuclear
2 byproducts have since been conducted and replicated as noted in **Enclosure 1**.

3 The **Cooke et al** reference, page 5, where Harwell also failed to gather positive
4 data on Frascati type experiments, as well as the F&P type, is as expected by the
5 applicants. (See **Remarks 11, 12, 13 & 14**.)

6 *Again, the **Cooke** report on the rather extensive **Harwell** effort does not reflect on*
7 *the efficacy of the approach employed in the present invention.*

8 **Quoting p. 5, beginning line 11:**

9 "The applicants specification contains assumptions and speculation as
10 to how and in what manner, his invention will operate. However, applicant has
11 presented no factual evidence to support his assumption and speculation that
12 when Pd metal has deuterium absorbed or adsorbed therein, the deuterium
13 nuclei can be caused to undergo nuclear fusion to produce heat. The
14 disclosed utility is a power producing system responsive to load demands (e.g.
15 see page 12 of the specification). However, there is no reputable description
nor enabling disclosure of an operating nuclear fusion system or process which
could actually produce such useful amounts of energy."

16 **Remark 16a:**

17
18 The reality of the deuterium fusion in a metal lattice took more than a decade to
19 confirm beyond reasonable doubt. The extremely low reaction rates demonstrated in
20 almost all experiments to date has made the effect difficult to detect without extreme
21 care in procedures and without some rather sophisticated equipment. The applicants
22 might well have been among the skeptics except for the few instances of high density
23 heat having been produced as noted in **Remarks 4 & 5** and is incorporated in the
24 revised Specification in Figure 9.

25 The reality of high density fusion heat is most dramatically described in
26 **Remark 5** and **Enclosure 7**. (Also see Figure 3, **Enclosure 5**.) It is from the
27 referenced experimental data, not from "assumptions and speculation", and with
28 considerable skills in the art of thermodynamics, material sciences and solid state
29 physics that the applicants evolved the present invention along with its operating
30 methods as noted in **Remarks 6, 7 & 8** and in numerous remarks that follow about
31 the methods noted in the Specification to implement the design.

32 The system for responding to load demands is now noted on page 19 of the
33

1 Specification. For a sealed reactor, see page 15 of the revised Specification.

2

3 **Quoting p. 5, beginning line 19:**

4 "There is no adequate description nor enabling disclosure of the
5 minimum concentration of the deuterium in the metallic catalyst (e.g. the D/Pd
6 ratio) that is necessary for the indicated fusion reactions to take place."

7 **Remark 17.**

8 All prior art is based on achieving the highest possible concentrations (D/Pd)
9 and there being a minimum, or 'threshold' concentration of deuterium in the
10 palladium metal for enabling the fusion reaction. Figure 2 in **Enclosure 5**, "This
11 Invention vs. Prior Art", shows typical data that led investigators to follow the course of
12 seeking high D/Pd concentrations. The prevalence of this belief in the need for high
13 concentrations caused investigators to concentrate on using the lower temperatures,
14 where a high concentration can be achieved. This principle, however, is correct for a
15 constant temperature, but is not generally true over a range of temperatures (see
16 Figure 3 in **Enclosure 5**).

17 The enabling method for this invention is distinct and is described in the
18 Specification in "How the Reactor Works", page 9. This enabling method is embodied
19 in the detailed operating procedures of the Specification.

20 *The invention disclosed herein sets no minimum D/Pd concentration. The D*
21 *concentration will be that concentration consistent with the temperature and pressure*
22 *required for the desired D chemical potential.*

23

24 **Quoting p. 6, beginning line 1:**

25 "There is also no adequate description nor enabling disclosure of how
26 and in what manner, the "minimum" concentration of deuterium in the metallic
27 catalyst is initially obtained and then maintained, so as to present an operative
28 device."

29 **Remark 18:**

30 For the invention disclosed herein, a specific minimum D concentration is not
31 required. (See Remark 17 above.)

32

33 **Quoting p. 6, beginning line 4:**

1 **"The specification on page 12 lines 12+ states that as the deuterium is**
2 **depleted (due to undergoing nuclear fusion) the power production rate for a**
3 **given temperature will decrease and, to compensate, the reactor is operated at**
4 **gradually higher temperatures over the life of the reactor (the disclosure,**
5 **however, is insufficient as to how and in what manner such is accomplished)."**

6 **Remark 19:**

7 The revised Specification includes a new section entitled "Useful life of the
8 Sealed Reactor", on page 17, to correct the noted deficiency in the old Specification.

9
10 **Quoting p. 6, beginning line 8:**

11 **"Said page 12 of the specification also implies that there is no minimum**
12 **deuterium concentration in the metal below which nuclear fusion will not occur**
13 **(the specification is insufficient as to the basis for such)."**

14 **Remark 20:**

15 As noted in **Remarks 17**, this invention relies on producing high system free
16 energies, corresponding to high D chemical potentials, to enable and accelerate the
17 fusion reaction. High D chemical potentials are achievable at high temperatures
18 where D/Pd concentrations are low. It is only necessary that 'some' deuterium be
19 present in the solid. The gas-metal system will remain in equilibrium (saturated) even
20 though the D/Pd ratio is small. As noted in Enclosure 9, at the bottom of Figure 4,
21 Krumbhaar measured some hydrogen in molten palladium at 1600°C in 1910.

22
23 **Quoting p. 6, beginning line 11:**

24 **"The disclosure is insufficient as to the minimum size of vessel 2, the thickness**
25 **and quantity of host metal, the concentration of deuterium in the host metal, the**
26 **deuterium gas pressure in the vessel 2, etc., necessary to present an operative**
27 **embodiment of applicants invention."**

28
29 **Remark 21:**

30 The Specification points out repeatedly that the design of the reactor for a
31 specific application depends on the application requirements. Typically, these
32 requirements are stated as: (1) a specific operating temperature and (2) a necessary
33 heat flux from the heat transfer surface. As an example, for an application requiring

1 radiant heat from a 'black body' surface, the requirements might be given as 15
2 watts/cm² from a black body surface at 1000°C.

3 The Specification (page 10) defines the methods for (1) selecting a host metal
4 (quality) and (2) measuring its power density over a range of operating chemical
5 potentials at the 1000°C operating temperature. These data provide (using Equation
6 1, page 10) a range of operating pressures for the selected host metal that will
7 provide reasonable power densities.

8 Using the required operating temperature and the highest pressure in the
9 range, an engineer will select an appropriate material for the reactor body (page 7 in
10 the Spec) from data sheets provided by suppliers of high temperature metals and
11 alloys. Using the supplier data sheets, the engineer will determine, by stress and
12 strength analysis, an optimum operating pressure, inside diameter and wall thickness
13 (size) for the reactor body. Using the optimum pressure and the measured power
14 density data for the selected host metal, the engineer can now select the proper
15 thickness of host material to install inside the reactor to satisfy the application heat
16 flux requirements.

17 ***The Specification provides the methods for selecting the host metal***
18 ***and measuring its heat-producing performance.*** From these data, the
19 necessary gas pressures are derived. From this point on, it is a 'textbook' approach
20 to pressure vessel design for anyone skilled in the art.

21 **Enclosure 6** summarizes the design approach and shows a typical
22 optimization design analysis including a spread sheet to develop the design
23 envelopes as they relate to temperature, pressure and chemical potential for
24 Carpenter's Pyromet 680 high temperature alloy. The Carpenter data sheet is also
25 included to show typical stress rupture data for using the material at temperatures
26 over about 600°C.

27

28 **Quoting p. 6, beginning line 15:**

29 "The disclosure is insufficient as to how and in what manner, the host
30 metal is 'distributed' inside the reactor vessel (including in 'deposited' form)."

31

31 **Remark 22**

32 The Specification is revised to add "Host Metal Installation" which now

33

1 describes three candidate methods of installing the host metal.

2

3 **Quoting p. 7, beginning line 1:**

4 "The specification on page 6 lines 18+ states the 'threshold chemical
5 potential of the host material' (and hence the operability of applicants
6 invention), is dependent on various factors including the purity, crystal size and
7 regularity, and the population of flaws, crack, vacancies, distortions and
8 dislocations in the crystal lattice structure of a particular host material.

9 "The disclosure however, is insufficient as to what point (e.g. the size
10 and extent of the population of cracks, the requisite degree of purity (and as to
11 what impurities would be permissible)S, etc.), any of these various factors (or
12 combinations thereof) would prevent operability.

13 "Further in this respect, the disclosure is insufficient and non-enabling
14 as to what effect such parameters as the porosity of the metallic lattice, the
15 degree, type and amounts of impurities in the metallic lattice, etc., have on the
16 ability of the indication nuclear fusion reactions to take place and thus present
17 an operative device."

18 **Remark 23:**

19 The method for selecting the host metal is expanded in the revised
20 Specification (page 10) to be more explicit that it is the measurement of the threshold
21 chemical potential of a candidate metal in its elected form that permits selection of the
22 best host metal; the best being that metal with a low threshold deuterium chemical
23 potential.

24 By this screening test method (such techniques being common in today's high
25 tech industries) the variation in the micro-properties of the host metal is summed in
26 the one macro-property, 'threshold deuterium chemical potential'. Some candidate
27 metals may be found to be inoperable and must be rejected. Once this property is
28 measured, there is an associated family of temperature and pressure combinations
29 that may be used in design to produce the threshold conditions.

30

31 **Quoting p. 7, beginning line 13:**

32 "There is no adequate description nor enabling disclosure of the
33 parameters of a specific operative embodiment of the invention, including
34 exact composition (including impurities and amounts thereof) of each of the host
35 metal, the filler material and the host metal support (the vessel wall material or
36 that of the hydrogen impervious coating thereon, if such is present), the
37 density of the host metal, the temperature and pressure inside the vessel, the
38 minimum concentration of deuterium in the host metal necessary for the nuclear
39 reactions to take place, the temperature to which the host metal must be heated
40 before nuclear reactions will take place, etc."

1

2 **Remark 24:**

3 All of the above items have been covered in previous comments by the
4 Examiner, and answered in previous remarks, except the one about the 'hydrogen
5 impervious coating'. In this instance, beryllium-bronze has been added in the
6 Specification, page 7, line 25, as a candidate impervious material. Anyone skilled in
7 the art of material sciences may choose to select an alternate material for that
8 purpose. Its precise selection is not critical to the operability of the present invention.

9

10 **Quoting p. 8, beginning line 1:**

11 "Applicants invention basically involves placing a hydrogen absorbing
12 metal in a container, causing deuterium to be absorbed into said hydrogen
13 absorbing material, which in turn, result in the deuterium undergoing nuclear
fusion reactions.

14 "However, the concept of storing deuterium in a vessel containing a
hydrogen absorbing material (including under high pressure and where heat is
15 applied) has been notoriously well known for many years. As examples thereof,
16 resort may be had to Klatt et al (I), McMullen et al, Carstens et al, and Schirber
et al.

17 "However, the systems as disclosed in these four examples were not
18 considered as being reactors wherein nuclear fusion took place.

19 "Indeed, if nuclear fusion did take place in said four examples, thus
causing the hydrogen isotopes to be depleted due to burn-up, the systems in
20 said four examples would have been rendered inoperative for their intended
and disclosed purposes."

21

22 **Remark 25:**

23 Yes, the concept of storing deuterium in a material, using high pressure and
24 heat has been well known for many years.

25 Klatt et al uses such storage, and utilizes the heat developed as deuterium is
26 introduced into the metal. This exothermic heat is also well known and is called
27 "heat-of-solution" by metallurgists. This is one of several well known heat effects
28 accompanying the entry of deuterium. The others are heat of dissociation, heat of
29 transformation and heat of ionization. None of the four are connected with excess
30 heat associated with deuterium fusion. They are relatively small, and are transient
31 heats that occur only at the time these three phenomena occur, and must not be
32 confused with the "excess heat". The excess-heat is associated with fusion and can
33 continue for long periods of time. Investigators of excess-heat associated with fusion,

1 routinely subtract the transient heats observed to calculate the "excess heat".

2 The maximum chemical potential achieved in **Klatt's** invention, during presence
3 of the transient heats, was on the order of 5kJ/mol when using palladium. There is no
4 reason to expect deuterium fusion to be enabled under the conditions noted for
5 **Klatt's** invention.

6 **McMullen et al** also use this well known exothermic heat-of-solution.

7 **Carstens et al** utilizes vanadium metal containing a hydrogen isotope to
8 produce high pressure by heating in a constant volume. This is well known in the art,
9 and is not connected to the production of excess heat connected with fusion which is
10 the subject of applicants invention. Further, it is **Carstens** "pump" principle by which
11 'pressure amplification' is achieved in the 'Sealed Reactor' version of this present
12 invention which uses the inert filler material to control the free-gas-volume of the
13 reactor. (See **Enclosure 11**.)

14 Also, the **Carstens** apparatus never produced D chemical potentials above
15 8kJ/mol which was well below that anticipated for enabling a fusion reaction in Pd.

16 **Schirber et al** utilized palladium hydride and deuteride to study the effect of
17 hydrogen or deuterium concentration on the superconducting transition temperature
18 of palladium. From the quoted temperatures and pressures (room temperature and
19 5kbars) **Schirber** produced D chemical potentials of only about 10 kJ/mol; again, too
20 low to enable a fusion reaction by gas loading.

21 *The Klatt et al, McMullen et al, Carstens et al and Schirber et al references cited*
22 *do not anticipate the present invention nor do they reflect on the efficacy of the*
23 *present invention.*

24 There have been many other investigations about the loading of metals with
25 deuterium. The question asked by the examiner is, since all such studies "load"
26 deuterium into a metal, and in some cases the metal was palladium, why didn't they
27 notice the excess heat due to fusion, and the decrease of the effect with the depletion
28 of deuterium. The answer is that it is unlikely that any of them produced the special
29 conditions (sufficiently high chemical potentials) required to enable excess heat as
30 described in the Specification page 5, line 23, to page 7, line 3. Had they produced
31 small amounts of low density excess heat, it would not have been noticed without
32 sophisticated heat detecting equipment. Fleischmann and Pons qualitatively noted a
33

1 suspicious effect in the late 1980's, and it took several years to identify it as not being
2 one of the well known heating effects, and to measure it. It has taken even longer to
3 reliably replicate the effect and quantify it.

4
5 **Quoting p. 8, beginning line 12:**

6 "Additionally, artisans such as Price et al actually attempted to obtain
7 nuclear fusion by subjecting deuterated Ti and Pd to temperature and/or
8 pressure cycling (e.g. note the first column on page 1926 of Price et al) all with
9 negative results.

10 "In contradistinction, applicant alleges that in systems of that type, the
11 deuterium instead, undergoes nuclear fusion reactions and thus said systems
12 can be utilized for power generation due to the heat generated from the nuclear
13 fusion reactions.

14 "Assuming for the sake of argument that applicants invention does
15 actually function in a different manner to produce a different result from that of
16 any of Klatt et al (I), Schirber et al, or McMullen et al, it can only be because
17 applicants invention actually contains some additional critical feature(s),
18 component(s), etc., not found in any of said referenced which is necessary to
19 enable applicants invention to function differently from any of said references
20 so as to be able to produce a different result.

21 "Accordingly, the disclosure is insufficient in failing to disclose said
22 additional critical features, components, etc., necessary to cause applicants
23 invention to operatively function in a different manner to produce a result
24 different from that of said references."

25
26 **Remark 26a:**

27 The following is in response to the last of the Examiner's comments above
28 about critical features:

29 A description of how the reactor works is on page 9 of the revised
30 Specification. The range of operating conditions in terms of the high operating
31 deuterium chemical potentials, high temperatures and moderate deuterium gas
32 pressures are shown in Figure 7 of the revised Specification. Based on that
33 description, the range of operating conditions and other specific requirements in
the Specification, the critical features of the invention are:

- Selection of the host material by measuring the threshold deuterium chemical
potential in a special test apparatus to provide the minimum operating
temperature and pressure combinations for enabling the fusion reaction.
(Specification page 10 and Claim 24)
- Measuring the heat densities of the host material over a range of operating

deuterium chemical potentials above the threshold in a special test apparatus to provide operating temperature and pressure combinations for design and operation. (Specification page 12 and Claim 25)

- The scanning reactor for measuring thresholds and power densities is the special test apparatus noted above. (Specification page 11, in Figure 6 and in Claim 22.)
- Enabling the fusion reaction by providing the measured threshold deuterium chemical potential in the reactor by control of the reactor temperature and the deuterium gas pressure. (Specification page 9 and Figure 7.)
- Generating heat by providing operating deuterium chemical potentials above the threshold in an amount consistent with the measured power densities and the installed palladium host. (Specification page 9 and Claims 26 and 27.)
- A heat transfer system to maintain temperature stability at the desired output. (Specification page 15.)

Remark 26b:

The following is in response the beginning comments above.

The work by Price et al did not measure heat but concentrated on nuclear effects measured during the experiment. Also see Remark 12 about the Price work not being expected to enable a fusion reaction.

The work of Fleischmann announced in 1989 reported excess heat and neutron emissions. The excess heat results were later confirmed, and the methodology well defended. The F&P work on neutron emission was found to be incorrect.

Most of the results reported in Enclosures 2 & 3 show lack of consistent correlation between the heat and neutron emission. These results and those by SRI noted in Enclosure 1, show that for a large number of cold-fusion tests, excess heat correlates with the measured generation of helium, but not with nuclear emissions.

The evidence from the SRI tests described in Enclosure 1 indicates that the cold fusion (or solid state fusion) produces largely helium-4, some small amounts of helium 3, and smaller amounts of tritium.

1 Neutron emissions are associated with the D-D production of helium-3 and the
2 D-T production of helium-4. Since the principal reaction in solid state fusion is the D-
3 D production of helium-4, neutron production would be very small corresponding to
4 the two lesser reactions; this making the detection of the small number of neutrons
5 very difficult even when a relatively large amount of excess heat is being produced.

6 One of the **critical features** of the present invention is that high system free
7 energy states, corresponding to high D chemical potentials, above a measured
8 threshold must be produced to enable and accelerate the fusion reaction. This critical
9 feature is not present in any prior art, including that by Klatt et al, McMullen et al,
10 Carstens et al, and Schirber et al. The D-chemical-potential, in turn is determined by
11 the temperature of the host, the D gas pressure inside the reactor, and is not a
12 function of the D/Pd concentration. All of the work by Price, et al, Klatt et al, McMullen
13 et al, Carstens et al, and Schirber et al was directed toward achieving high D/Pd
14 concentrations for hydrogen storage; *therefore these works do not reflect on the*
15 *efficacy of this present invention.*

16

17 **Quoting p. 9, beginning line 8:**

18 "There is no reputable evidence of record to support the assumption and
19 speculation that the invention would actually operate as indicated and, produce
20 the results as indicated."

21 See Remarks 4, 5, 6, 7, 8 and 26a and the revised Specification.

22

23 **Quoting p. 9, beginning line 10:**

24 "It is not seen wherein the specification discloses any particular
25 structure, etc., which is unique to applicants system and which would make
26 applicants cold fusion system operative where the systems disclosed the above
27 referenced "numereous teachings by skilled artisans", were not operative."

28 **Remark 27:**

29 The Specification is clear on the enabling and operating methods as noted in
30 "How the Reactor Works" on page 9. Remark 26a summarizes the critical features of
31 the present invention; none of which are present in the teachings of the noted "skilled
32 artisans". It is fortunate, indeed, that the "solid state" deuterium fusion phenomenon is

33

1 enabled by electrolysis at chemical potentials around 15 kJ/mol. Had this not been
2 the case, it might never have been discovered. High density heat is not possible by
3 electrolysis, and, if it were, it would not be an economic method due to the need for
4 the continuous application of power to achieve an excess.

5

6 **Quoting p. 9, beginning line 14:**

7

8

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"It is apparent from the specification that applicants' concept or theory
involving a "cold fusion" system that came about from the work of F & P, is
workable or operative, only if these systems are already operative."

10 **Remark 28a:**

11

12 The examiner's statement is based on there not being any possibility of
13 deuterium fusion taking place in a palladium host. Please revisit **Remark 2** and
14 **Enclosures 1, 4 & 7.**

15

16 **Quoting p. 9, beginning line 17:**

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"However, as set forth above, the examiner has presented evidence
showing that in such cold fusion systems, the claims of excess heat (as well as
of other nuclear reaction products), are not reproducible or even obtainable. It
consequently must follow that the claims of excess heat are not reproducible or
even obtainable with applicants invention. While applicant may have set forth
theoretical concepts, it is well known in the cold fusion field that theory and
reality have a habit of not coinciding. There is no evidence to indicate applicant
has so succeeded where others have failed, in arriving at an operable cold
fusion system, i.e. that he has progressed his system beyond the point of an
unproven theory or concept which still requires an undue amount of
experimentation to enable the artisan to make and use the invention system for
its indicated purpose. This view is also considered supported by the failure to
set forth a full of the specific parameters of an operative embodiment which
would produce the indicated heat output."

27 **Remark 28b:**

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Examiner's evidence that **excess heat is not obtainable or reproducible** is his
basis for declaring the applicants' invention inoperable. This evidence is obsolete
and is now replaced by evidence to the contrary. Please see the revised background
of the invention on page 1 of the specification and the power density data in Figure 9.
Also please revisit **Remark 2** and **Enclosure 1.**

1 In addition, all prior art is based on achieving high D/Pd loading ratios which is
2 limiting all work to low temperatures and the attendant low power densities. Pursuit of
3 high D/Pd loading ratios is not consistent with the available experimental evidence of
4 high density heat. (See Enclosure 5.)

5 Applicants have set forth a clear distinction between their invention and all prior
6 art in the Specification and as summarized in **Remark 26a.** and **Enclosure 5.** The
7 applicant's **theoretical concepts** are correctly founded on the principles of
8 thermodynamics, material sciences and solid state physics and, most important of all,
9 are consistent with existing experimental data. Applicants have progressed their
10 system beyond the point of an unproven theory or concept as evidenced in the
11 revised specification and believe that the systems and methods set forth in the
12 Specification make this invention operable and suitable to be practiced by artisans
13 with skills in the fields indicated.

14

15 **Quoting p. 10, beginning line 8:**

16 "One cannot rely on the skill in the art for the selection of the proper
17 quantitative values to present an operative cold fusion system, since those in the art
18 do not know what these values would be. See Bank v. Raluland Corp., 64 U. S. P.
19 Q93; In re Cornell et al 145 U.S.P.Q. 697."

19

20 **Remark 28c:**

21 The methods for selecting the proper qualitative values are now clear in the
22 revised Specification. It is true that anyone wishing to practice this invention would
23 require skill in more than one field such as high temperature pressure vessel design,
24 heat transfer design, material sciences, laboratory safety in the handling of
25 pressurized hydrogen, etc. The Specification is presented in brief sections so that the
26 person practicing the invention will recognize where special skills may be needed.

27 No effort is made in the specification to teach applicable skills and technology
28 that are readily available in texts and in universities. The principle exception to this
29 general rule, is the inclusion of Technical Note TN-7.1, Reference 5, which iterates
30 the founding free energy thermodynamic principles and derives Equation 1, page 10,
31 that is used to carry out the methods set forth in the Specification. The technology
32 presented in TN-7.1 is not generally practiced by electrochemists and is not easily
33 extracted from the literature and texts. It is obvious that none of the artisans who

1 practiced gas loading techniques in the many experiments cited by the Examiner
2 understood the technology presented in TN-7.1.

3 Another exception is the presentation of the "D-Pd TCP Equilibrium Diagram" in
4 Figure 8. This equilibrium diagram is used in the design and control of sealed
5 reactors as required in the Specification. It was developed by the applicants
6 specifically for this invention from fragmentary experimental data published over a
7 period of perhaps 100 years. The development of this comprehensive equilibrium
8 diagram is described in TN-2.0 in Enclosure 9.

9

10 **Quoting p. 10, beginning line 11:**

11 "To reiterate briefly, the examiner has presented evidence, that neither
12 the situation of excess 'heat' nor of other, nuclear reaction products, can
13 reasonably be expected to be reproducible or even obtainable with the present
14 invention.

15 "There is no reputable evidence of record that would overcome the
16 experimental showings in the above listed references, disproving this concept
17 of "cold fusion".

18 "Again, there is no reputable evidence to indicate applicant has so
19 succeeded where others have failed, in arriving at an operative system that
20 produces nuclear fusion or even "excess" heat, i.e., that he has progressed his
21 system beyond the point of an unproven theory of concept which still requires
22 and undue amount of experimentation to enable the artisan to make and use
23 the invention for its intended purpose."

24

25 **Remark 28d:**

26 Applicants have presented evidence that **excess heat and generation of helium**
27 **by fusion of deuterium** is obtainable with the present invention as described in the
28 Specification "Background of the Invention", in Reference 6 and in Figure 8 in the
29 Drawings which depict experimental data in terms of power density. Arguments that
30 excess heat and nuclear byproducts have not been proven to occur in the deuterium-
31 palladium system are no longer reason to declare this invention inoperable.

32 Applicants have reiterated the critical features found in the Specification for this
33 invention in **Remark 26a**. *Additionally, they have shown that the numerous*
references cited in the Examiner's comments neither incorporated the critical features
of this present invention nor anticipated this present invention. None reflect on the
efficacy of this present invention.

Also, please see **Remark 32** further on.

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Quoting p. 11, beginning line 1:

"It is thus considered that the examiner (for the reasons set forth above) has set forth a reasonable and sufficient basis for challenging the adequacy of the disclosure. The statute requires the application itself to inform, not to direct others to find out for themselves; In re Gardner et al, 166 USPQ 138, In re Scarbrough, 182 USPQ 298. Note that the disclosure must enable a person skilled in the art, to practice the invention without having to design structure not shown to be readily available in the art. In re Hirsch 131 USPQ 198."

Remark 29:

The revised specification now includes description of the reactor and systems together with the methods in sufficient detail for a person skilled in the art to practice the invention without having to design structure available in the art. Also see

Remark 28c.

Quoting p. 11, line 7: (Par. 4.)

"Claims 1, 3, 4, 5, 17, 19 are rejected under 35 U.S.C. Section 112, first paragraph for the reasons set forth in the objection to the specification in section 3 above."

Please revisit **Remarks 1 thru 29.**

Quoting p. 11, beginning line 9:

"35 U.S.C. 101 reads as follows: Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title."

(No remarks required.)

Quoting p. 11, beginning line 13:

"Claims 1, 3, 4, 5, 17, 19 are rejected under 35 U.S.C. 101 because the invention as disclosed is inoperative and therefore lacks utility."

Please revisit **Remarks 1 thru 29** and in the revised Specification.

Quoting p. 11, beginning line 15:

1 "The reasons that the invention as disclosed is [in]operative are the
2 same as the reasons set forth in section 3 above as to why the specification is
3 objected to and the reasons set forth in said section 3 above are accordingly
4 incorporated herein."

5 (Note: The brackets[] above denote the assumed intent of
6 the examiner.)

7 Please revisit Remarks 1 thru 29.

8 Quoting p. 12, beginning line 3:

9 "Applicant at best, has set forth what may be considered a concept or an
10 object of scientific research. However, it has been held that such does not
11 present a utility within the meaning of 35 U.S.C. 101. See Brenner v. Manson,
12 148 U.S.P.Q. 689."

13 (Note that remark numbers 30, and 31 are not used.)

14
15 **Remark 32:**

16 Virtually all prior art has been performed in the interest of scientific research.
17 Most experimental work, even today, is characterized by a dogmatic pursuit of high
18 D/Pd loading ratios at low, or moderately low, temperatures where power densities
19 are very low and difficult to measure. The current approach by today's artisans offers
20 little or no possibility of significant improvement due to the limitations on the
21 electrolytic processes and the natural limit on loading ratio. None have specified an
22 operable system that is economic and can be used in a commercial application.
23 None of the 'gas loading' type of experiments enabled a fusion reaction because they
24 lacked the essential critical features of this invention.

25 On the other hand, this invention is distinguished by its high utility due to
26 producing high density heat at high temperatures; the two key ingredients to make
27 applications of the invention economic and commercially viable. The Specification
28 describes the reactor and systems with the methods necessary to implement a
29 practical design.

30
31 Quoting p. 12, beginning line 6:

32 "Additionally, it is well established that where as here, the utility of the
33 claimed invention is based upon allegations that borders on the incredible or
allegations that would not be readily accepted by a substantial portion of the

1 scientific community, sufficient substantiating evidence of operability must be
2 submitted by applicant. Note In re Houghton, 167 USPQ 687 ((CCPA 1970): In
3 re Ferens, 163 USPQ 609 (CCPA 1969); Puharich v. Brenner, 162 USPQ 136
4 (CADC 1969); In re Pottier, 152 USPQ 407 (CCPA 1967); In re Ruskin, 148
5 USPQ 221 (CCPA 1966); In re Citron 139 USPQ 516 (CCPA 1963); In re Novak,
6 134 USPQ 335 (CCPQ 1962)."

6 **Remark 33:**

7 Of the quoted references, the case concerning Ferens most closely parallels
8 examiner's summary statement. We partially quote from the "Cumulative Digest",
9 case 163 USPQ 609: (See the full text of the Ferens summary in **Enclosure 12**)

10 (The underlining shown in the quoted text below was inserted by the applicant.)

11 "..... since purpose of patent system is to encourage attainment of previously
12 unachievable results; however, where applicant predicates utility for claimed invention on
13 allegations which border on the incredible in light of contemporary knowledge of the particular art
14

14 "..... evidence submitted to establish usefulness must be such as would be clear and
15 convincing to one of ordinary skill in the particular art."

16
17 It is true that in 1989 and 1990, many of the scientific community, including
18 many competent and sincere scientists, considered the "cold fusion" allegations as
19 "bordering on the incredible". These were practitioners who had tried to duplicate the
20 excess heat or nuclear effects and failed; others convinced by such negative results;
21 still others assumed that when certain nuclear side effects produced during hot fusion
22 were not present during "cold fusion", therefore the cold-fusion could not have
23 occurred.

24 Some of this group, who have not been in touch with subsequent work in the
25 field, have not changed their opinion.

26 But, referring to the quote from the Ferens case noted above, the operative
27 phrase is "clear and convincing to anyone of ordinary skill in the particular art". This
28 must be construed as referring to the technical community of several hundred in over
29 7 countries, who have been working in the field for the past 12 years, have written
30 over 1,500 technical papers (many peer reviewed), conducted 8 international
31 conferences, and many local conferences.

32 This small group of artisans have "ordinary skill in the particular art" and
33

1 consider the evidence "clear and convincing" that excess heat connected with
2 deuterium fusion at reasonably low temperatures, is a reality. The specification in this
3 invention will be clear to many of them.

4 Please revisit **Remark 32**.

5

6 **Quoting p. 12, lines 13 thru 15:**

7 "Claims 1, 3-5, 17, 19 are rejected under U.S.C. 112, second paragraph,
8 as being indefinite for failing to particularly point out and distinctly claim the
9 subject matter which applicant regards as the invention."

10 Please see revised claims starting on page 21 of the revised Specification.

11

12 **Quoting p. 12, line 16:**

13 "Claim 1 improperly ends in a semi-colon rather than a period."

14

15 Please see revised claims starting on page 21 of the revised Specification.

16

17 **Quoting p. 12, beginning line 16:**

18 "As indicated in section 3 above, the examiner has cited several documents,
19 e.g., Schirber et al, Carstens et al, Klatt et al (I) and McMullen et al, which disclose
20 systems which are considered identical to that which is disclosed and claimed by
21 applicant and said systems are operated on in the same manner as applicants
22 invention and that accordingly said systems in said "several documents" must
23 inherently function in the same manner to produce the same result as that of
24 applicant.

25 "Assuming for the sake of argument that applicants invention does actually
26 function in a different manner to produce a different result from that of any of said
27 "several documents" it can only be because applicants invention actually contains
28 some additional, critical feature(s), component(s), etc., not found in any of said
29 "several documents" which is necessary to enable applicants invention to function
30 differently from any of said "several documents" which is necessary to enable
31 applicants invention to function differently from any of said "several documents" so
32 as to be able to produce a different result.

33 "Accordingly applicants claims are incomplete (as well as vague and indefinite)
in failing to recite said additional critical feature(s), component(s), etc."

34

35 **Remark 34:**

36 The "several documents" cited did not employ critical features included in this
37 invention. The critical features are clear in the Specification and are summarized in

38 **Remark 26a.**

Also, please see the revised claims presented in the Specification starting on page 21.

Quoting p. 14, lines 8 thru 14:

"The applicant currently names joint inventors. In considering patentability of the claims under 35 U.S.C 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was in order for the examiner to consider the applicability of 35 U.S.C. 103© and the potential 35 U.S.C. 102(f) or (g) prior art under 35 U.S.C.(a)."

(Remark numbers 35 and 36 are not used.)

Remark 37:

All claims are jointly owned by the two applicants, Waisman and Summerl.

Quoting p. 14, lines 15 to 20:

"Claims 1, 3, 4, 19 are rejected under 35 U.S.C. 102(b) as being anticipated by any of Price, et al, Carstens et al, Schirber et al, Klatt et al (I) or McMullen et al.

"Note that the references each disclose the same structure or system as in [is] recited in the claims and it is acted on in the same manner. Accordingly, this system of any of the references must also inherently function in the same manner to produce the same result as that of applicants claims.

Remark 38:

The cited documents do not anticipate this invention since they did not include systems and methods incorporated in this invention. See **Remark 26a**.

Quoting p. 15, lines 1-3:

"As to limitations which are considered to be inherent in a reference, note the case law of In re Ludtke, 169 USPQ 563, In re Swinehart, 169 USPQ 226. In re Fitzgerald, 205 USPQ 594, In re Best et al, 195 USPQ 430, and In re Brown, 173 USPQ 685, 688."

1 Remark 39:

2 The Fitzgerald case, 205 USPQ 594, closely parallels Examiner's comment and
3 a portion is quoted here from the Cumulative Digest:

4

5 ".....; Patent Office can require applicant to prove that prior art products do not
6 necessarily or inherently possess characteristics of his claimed product;"

7 To respond to this statement, we refer to our **Remarks 40, 41, & 42** which
8 follow.

9

10 Quoting p. 15, beginning line 4:

11 "Claims 1,3, 5, 19 are rejected under 35 U.S.C. 102(b) as being clearly
12 anticipated by either Arata et al or Scaramuzzi et al."

13 Remark 40:

14 Applicant's invention is entirely different from Arata's disclosure and is therefore
15 not anticipated by it. In Arata's disclosure, the expressed principle of operation is to
16 keep the D/Pd concentration high by keeping the pressure high and the temperature
17 low. This is shown in the following quotation from p. 8 of the English translation, lines
18 3 through 5:

19 "Also, the saturated deuterium concentration for the palladium powder is high as long as
20 the pressure of the peripheral deuterium is high and the temperature is low as well."

21 Also, Arata employs temperatures, and resulting free energy states, far below
22 those employed in applicant's invention as shown by the following quotation from
23 page 8 of the English translation, lines 12 through 18:

24 "Based on a normal pressure, if the temperature of the palladium that absorbs deuterium
25 is raised, as shown in Fig. 11, the temperature migrates from regions A, in which deuterium is
26 absorbed, to region B, in which deuterium is given off suddenly close to 105 C. Also if the
27 temperature is lowered, deuterium is absorbed suddenly near 80 C, and the temperature returns
28 to region A."

29 Arata's disclosure is based on electrolytic loading and suffers from the low
30 temperature limitations of the electrolyte and the natural limit on the D/Pd loading
31 ratio. The low free energy states possible in Arata's disclosure prevent the possibility
32 of high density heat. While Arata did produce low density excess heat and nuclear
33 byproducts, *it is clear that Arata did not anticipate this present invention.*

1 In the **Scaramuzzi** disclosure, the loaded system is cycled from D pressure in the
2 range of 40 bar to 1/100 Torr, and the temperature cycled from 77 K to 300 K. As
3 noted in **Remarks 11** thru **15** and **26b**, where others tried to replicate
4 **Scaramuzzi's** results, the procedure was designed to maximize the D/Pd loading ratio
5 and made no attempt to achieve high system free energy states. The maximum D
6 chemical potential achieved by **Scaramuzzi** was less than 5 kJ/mol as calculated
7 using the equation in this present Specification, page 6. line 11 and the 300K
8 temperature and the 40 bar deuterium gas pressure: $[\mu = 0.5 \cdot 8.32 \cdot 300 \cdot \ln(40) =$
9 $4.6 \text{ kJ/mol}]$. This maximum system free energy state is far below the threshold
10 required to enable a fusion reaction in a gas loaded system. *It is obvious that*
11 *Scaramuzzi did not anticipate this present invention.*

12

13 **Quoting p. 15, lines 6, 7:**

14 "Claims 1, 3, 5, 17, 19 are rejected under 35 U.S.C. 102 (b) as being clearly
15 anticipated by Yamamoto et al."

16 **Remark 41:**

17 The **Yamamoto et al** patent is for a device to store hydrogen isotopes in a metal
18 solution. It employs two or more different absorbing materials, selected so that
19 cycling the combination of the two, has an effect of 'pumping' the hydrogen, from the
20 exterior to the interior. This invention states it can be used for a number of storage
21 purposes, including with electrolytically loaded palladium producing "cold fusion",
22 but otherwise does not disclose a 'cold-fusion' device.

23 One cannot tell from the **Yamamoto** disclosusre whether or not excess heat was
24 ever actually produced in connection with electrolytically loaded deuterium for the
25 specific material used. If excess heat had occurred during loading of the storage
26 device, it would not have been detected in the absence of appropriate measuring
27 sensors. Assuming that 'cold fusion' had occurred, it would have been of the very low
28 power density characteristic of prior art electrolytic loading.

29 **Yamamoto** uses loading temperatures up to 50°C and pressures only up to that
30 which can be supplied by a pressurized container, or "gas bomb", (Item 9, Figure 5).
31 Even at "gas bomb" pressures of 200 atmospheres, the highest D chemical potential
32 available would be only about 7 kJ/mol; well below the threshold for a gas loaded

33

1 system.

2 *It is clear that Yamamoto did not anticipate this present invention.*

3

4 **Quoting p. 15, beginning line 8:**

5 "Claims 1, 3, 4, 17, 19 are rejected under 35 U.S.C. 102(b) as being clearly
6 anticipated by any of Aiello et al, Wada et al, Hasegawa et al, or Focardi et al."

7

8 **Remark 42:**

9 The tests conducted by Aiello et al were all nuclear side-effect tests and the
10 system free energy state achieved by Aiello was extremely low and would not be
11 expected to enable a deuterium fusion reaction.. Aiello's work is similar to the work of
12 Friedman, Price, McCracken, Badurek, Cooke, Harwell, Hadjas, all of which failed to
13 incorporate the critical features of this present invention and therefore none
14 anticipated this present invention nor do they reflect on the efficacy of this present
15 invention. As we have shown in **Remark 26b**, the type of fusion reactions
16 characteristic of "solid state" fusion and in the applicants' invention is characterized
17 by heat and the accompanying He formation; not by significant other nuclear side
18 effects.

19 Similarly the Wada et al work and the Hasegawa et al work also deal only with
20 nuclear side-effects and utilize electrostatic loading requiring the continuous
21 application of electric power to maintain the deuterium loading.. It is clear that Wada's
22 and Hasegawa's work neither anticipate this present invention nor do they reflect on
23 its efficacy.

24 The Focardi et al tests were run with nickel metal and hydrogen gas, at
25 pressures below one atmosphere. (Part of the discussion included deuterium, but
26 hydrogen was used in the experiment.)

27 *It is clear that the Focardi work neither anticipates this present invention nor*
28 *does it reflect on its efficacy.*

29 **Quoting p. 15, line 10:**

30 "The other references cited further illustrate pertinent art."

31

32 **Remark 43:**

33 Previous remarks include comments on all paragraphs in examiner's letter and
all references cited.

(End of Remarks)

1 **DEUTERIUM HEAT GENERATOR**

2 **CIP-2** (CIP-1 No. 09/348,142 filed 07-02-99. Parent Application No: 08/917,147
3 filed 08-25-97.)

4

5 Inventors:

6 Joseph L Waisman, 25 Redwood Tree Lane, Irvine, California, 92612 and

7 Richard H. Summerl, 11051 Arroyo Ave., Santa Ana, California 92705.

8

9 Cross-References:

10 Disclosures filed by the inventors at the Patent & Trademark Office, Washington D.C:

11 1. Disclosure Document Number 381513 dated August 31, 1995.

12 2. Disclosure Document Number 401865 dated June 28, 1996.

13 ~~U.S. Patents referenced:~~

14 ~~3. U. S. Patent No. 5,607,563, Patterson, March 4, 1997.~~

15 Other references (enclosed):

16 4. "The Pathway to Commercial Applications", by J. L. Waisman and R. H.

17 Summerl, the Proceedings of the Seventh International Conference on Cold

18 Fusion, held in Vancouver, British Columbia, Canada, April 19-24, 1998, p

19 414.

20 5. Technical Note TN-7-0 7.1 "The Thermodynamic State of a Gas/Solid System"

21 issued by J. L. Waisman & R. H. Summerl, ~~5-16-99~~ revised 9-20-99.

22 6. "The Emergence of a Coherent Explanation for Anomalies Observed in D/Pd

23 and H/Pd Systems: Evidence of 4He and 3He " by Michael McKubre, et al.

24 ICCF-8, March 2000.

25

26 **Background of the Invention**

27

28 ~~In a series of investigations, starting in the late 1980's, a new continuous, low-~~

29 ~~level, heat-producing reaction was identified that takes place after deuterium is~~

30 ~~introduced into palladium by electrolysis. At temperatures under 100°C , the power~~

31 ~~densities were less than about 100 watts per cubic centimeter of palladium.~~

32 ~~Patterson and Gravens, Patent Number 5,607,563, claim an electrolytic cell~~

33 ~~which develops a low-level heat resulting from a hydrogen or deuterium reaction. In~~

34 ~~investigations at temperatures above 400°C , by Fleischmann & Pons, heat was~~

1 ~~produced in a deuterium-palladium system, after extended electrolysis, at a rate~~
2 ~~above 1 kilowatt per cubic centimeter of palladium in an uncontrolled manner when~~
3 ~~the electrolytic process was halted by removing the electrolyte.~~

4 ~~Scientific data, dating back to 1863, show that hydrogen will dissolve in some~~
5 ~~metals by gas pressure alone. Much of this published data describes the behavior of~~
6 ~~hydrogen and/or deuterium in palladium. These data generally present the hydrogen~~
7 ~~concentration in a metal for various combinations of temperature and pressure. A~~
8 ~~number of these data were re-plotted on a common format, by the present inventors,~~
9 ~~resulting in a comprehensive Deuterium-Palladium TGP Equilibrium Diagram useful~~
10 ~~in determining thermodynamic state and comparing experimental results. (Ref. 4 & 5)~~

11 In the 1980's, Fleischmann and Pons (F&P) discovered that excess heat was
12 produced when electrolyzing heavy water using a palladium (Pd) cathode. Their
13 1989 announcement brought on a rash of hurried experiments by the technical
14 community to try to replicate the effect that had become known as "cold nuclear
15 fusion". Most such experiments failed; some for good cause. F&P sometimes had
16 trouble replicating their own work. Nuclear physicists denounced the cold fusion
17 effect because they believed that: (1) the same radiation products of deuterium fusion
18 that had been experienced in 'hot fusion' should have been detected and (2) the
19 Coulomb repulsion forces could be overcome only when temperatures in the
20 100,000,000°C range are produced. Cold fusion was branded as an incredible hoax
21 and virtually all funding in the United States was halted.

22 Throughout the 1990's, a number of dedicated scientists in laboratories around
23 the world continued the research. More and more were successful in producing
24 excess heat by electrolysis and some succeeded in measuring the helium products of
25 the reaction. The heat generation densities were low and the helium measured was
26 very small and did not show a consistent relationship with the timing and rate of heat
27 production. In all cases, investigators were pursuing the highest possible
28 concentrations of deuterium in the palladium lattice as the enabling process; the
29 highest concentrations being achieved at lower temperatures.

30 Some groups tried to achieve high D/Pd concentrations by gas loading but
31 were unable to reach the ultra-high gas pressures to equal the high equivalent
32 pressures achieved by electrolysis.

33 Other groups gave gas loading their best effort hoping to measure energized
34 particle radiation from the deuterized palladium and other hydrogen absorbing

1 metals. Again their efforts were spent in trying to achieve very high D/Pd
2 concentrations. Such experiments all failed for not recognizing that high temperature
3 is a key ingredient for enabling a fusion reaction by gas loading.

4 More recently, four successful experiments which produced excess heat and
5 showed the helium byproducts, that had been performed in four different laboratories,
6 were carefully replicated at SRI, Int. (See Reference 6.) This replication work
7 removes doubt about the reality of cold nuclear fusion which is now becoming known
8 as 'solid state fusion'.

9 But for one notable exception, all of the reaction rates were very low and of little
10 practical use. In their very early work, F&P actually produced high density heat,
11 accidentally at first and later in controlled experiments. This was their "boil dry" work
12 which they reported as "ignition" in the accidental case and "heat after death" in their
13 controlled boil dry experiments where the heavy water electrolyte was allowed to boil
14 away and the palladium cathodes became very hot for a long period of time. The data
15 from this boil dry work is shown on a plot of power density vs temperature in Fig. 9 to
16 illustrate the significant effect of temperature in the production of high density heat.

17 It was this experimental work and other electrolytic work conducted at
18 somewhat elevated temperatures that captured the attention of the present inventors
19 who realized that the reaction rate was very much a function of temperature. The
20 higher heat densities at higher temperatures could easily be correlated to
21 thermodynamic principles but could not be correlated to higher D/Pd concentrations.
22 High D/Pd concentrations at elevated temperatures cannot be achieved as noted on
23 the equilibrium diagram for the deuterium-palladium system in Fig. 8.

24 The present inventors focused on the application of thermodynamic principles
25 that would cause one to look, at an elevated system-free-energy state, for a 'change of
26 state' of the deuterium within the confines of the metal lattice and that would enable
27 the fusion reaction; a change that nullifies the Coulomb repulsion forces and makes a
28 nuclear process possible. While this is a 'macro' point of view, it is now born out by
29 very credible 'micro' theories currently being developed by solid state physicists.

30 The present inventors also focused on the necessary requirements for there to
31 be commercial applications. For the cost of power production by this new method of
32 heat generation in palladium to be competitive with heat produced using fossil fuels, it
33 is necessary that it produce high density heat without the continuous input of power as
34 is required by the electrolytic methods. The present invention will produce heat

1 densities that are suitable for commercial applications at high temperatures without
2 the continuous use of power.

3

4 **Brief Summary of the Invention**

5

6 ~~The invention consists of (1) a pressure vessel reactor containing a metal, such~~
7 ~~as palladium, which has a crystal lattice structure capable of hosting a deuterium~~
8 ~~heat-producing reaction, (2) a reactant gas, deuterium, and (3) a method of initiating~~
9 ~~and controlling the heat-producing reaction. The method employs means for: (1)~~
10 ~~dissolving deuterium in the host metal, (2) raising the chemical potential of the~~
11 ~~dissolved deuterium until the heat-producing reaction is enabled, (3) controlling the~~
12 ~~rate of heat production by controlling reactor temperature and the deuterium gas~~
13 ~~pressure, (4) controlling the reactor temperature and the stability of the reaction by~~
14 ~~controlling the heat transfer rate, and (5) extracting the generated heat by utilizing a~~
15 ~~suitable heat transfer system.~~

16 The present invention is a reactor and system with a method for containing and
17 controlling a deuterium nuclear fusion reaction in a host metal lattice, such as
18 palladium, now generally referred to as 'solid state fusion'. The reactor is designed
19 for high temperature operation at moderate deuterium gas pressures and is operable
20 over a temperature range of 400°C to more than 1400°C. Temperatures up to 3000°C
21 are achievable for host metals with high melting temperatures.

22 The solid state fusion reaction is enabled and controlled by providing specific
23 combinations of reactor temperatures and deuterium gas pressures in the host metal's
24 surroundings. Free energy thermodynamic principles are applied to determine the
25 specific combination of temperatures and pressures for enabling and controlling the
26 fusion reaction. They involve providing a high system free energy state,
27 corresponding to a high deuterium-chemical-potential, that is above the threshold for
28 a 'change of state' of the dissolved deuterium where it can and will achieve a new
29 lower free energy. It is this 'change of state' that nullifies the Coulomb repulsion
30 forces and permits fusion to occur. (See the definition of chemical potential given
31 later.)

32 The deuterium, D, chemical potential is controlled by controlling the D gas
33 pressure, P, and the reactor temperature, T. It must be remembered that for
34 every value of D chemical potential, there is a specific associated family

1 of temperature and D gas pressure combinations that will produce that
2 same chemical potential value as is seen in Fig. 7. The fusion reaction is
3 accelerated by increasing the operating D chemical potential, above the threshold.

4 To provide metals capable of hosting the reaction, a selection process of
5 testing candidate host metals in a 'scanning reactor' is used to determine reaction
6 thresholds and heat rates. The measured threshold chemical potential establishes
7 the minimum operating conditions, temperature and pressure combinations, for the
8 onset of heat production for a particular host metal and form. The measured heat
9 production rates provide the temperature and pressure combinations necessary to
10 achieve a desired heat production rate.

11 A means for stabilizing the temperature of the reaction by controlling the heat
12 transfer rate is provided in the heat transfer system.

13 The reactor may be permanently sealed after 'loading' the deuterium, allowing
14 the reactor to be stored and then operated separate from its deuterium pressurizing
15 equipment. Use on a moving vehicle that requires portability of its energy source
16 would be a typical candidate application for the sealed reactor. An inert filler material
17 in the void space of the sealed reactor may be used to reduce the gas volume inside
18 the reactor thereby amplifying the pressure increase achieved with increasing
19 temperatures. For the amplification to be large, the void space volume must be
20 reduced to be on the same order as that of the palladium. The life of a sealed reactor
21 is limited due to the depletion of deuterium as helium is formed.

22 The heat-producing reaction is self-sustaining once started enabled.

23

24 **Brief Description of the Drawings**

25

26 ~~Figures 1 and 2 show longitudinal and transverse cross-section views, respectively, of~~
27 ~~a typical reactor indicating the arrangement of the host metal on the inside and of the~~
28 ~~heat transfer surfaces on the outside.~~

29 Fig. 1 is a longitudinal cross-section of a typical reactor showing the general
30 arrangement of the host metal inside of the pressure vessel and the enabling heater
31 (coil) on the outside surrounded by the heat transfer surface. The configuration
32 shown in Fig. 1 is typical for heat transfer by radiation where the outer surface has a
33 high emissivity. The enabling heater may be integrated into the heat transfer system if
34 desired, rather than in the heat transfer surface, as is illustrated in Fig. 4 and in the

1 schematic in Fig. 5. They Fig 1 also shows the location of the permanent seal when
2 used, the inert filler material when used, and the thermocouple when used.

3 Fig. 2 shows the same typical reactor except with fins integrated into the heat
4 transfer surface for heat transfer by convection.

5 Fig. 3 is a transverse cross-section of the reactor.

6 Fig. 4 is an alternate arrangement where the host metal is located in a position
7 other than on the inside surface of the outer wall of the pressure vessel. Here the
8 enabling heat is provided by externally heating the heat transfer fluid during start-up.

9 Figure 3 & 5 is a typical schematic of the reactor and its operating system for heat
10 generation when the heat transfer method is by forced convection. Included are
11 ~~deuterium loading, heat transfer and stability control.~~ Alternate control systems may
12 be employed to suit the application requirements.

13 Fig. 6 shows a general arrangement of the scanning reactor, the temperature
14 probe and a typical test sample.

15 Fig. 7 is a plot of the 'System Free Energy State' versus 'Operating
16 Temperature' showing the range of operating chemical potentials, and the associated
17 temperatures and pressures, over which the present invention is operable. An
18 extended range is also noted.

19 Fig. 8 is the Deuterium-Palladium TCP Equilibrium Diagram.

20 Fig. 9 is a plot of selected experimental data showing where high density heat
21 was produced at high temperatures.

22

23 **Detailed Description of the Invention.**

24

25 **The reactor assembly:**

26

27 Referring to the Fig's. 1 and 2, the deuterium heat generator 1, is hereafter
28 called the 'reactor' or the 'reactor assembly'. The reactor assembly 1 consists of: the
29 pressure vessel 2; the host metal 3; the enabling heater 34; the heat transfer surfaces
30 4; a high pressure gas connector 5 to facilitate connection to the high pressure
31 manifold 13; a permanent sealing device 6 when used; an inert filler material 7 when
32 used; and a temperature transducer 8 when used to determine the approximate host
33 metal temperature. The heat transfer surfaces 4: may be plain; may have fins for heat
34 transfer by convection; or may have a high emissivity coating for heat transfer by

1 radiation. Heat transfer by a combination of convection and radiation may also be
2 employed when that best suits the requirements of the application.

3 The reactor assembly 40 in Fig. 4 illustrates how the host metal 3 may be
4 located in an alternate location in the pressure vessel. In this instance, the control
5 schematic (not shown) would embody the same principles that are embodied in the
6 schematic shown in Fig. 5.

7 When the reactor is to be permanently sealed, the opening to the reactor
8 assembly must include a suitable device 6 and method for sealing at its
9 predetermined 'loading' temperature and pressure. Such a device is one that
10 provides a slightly tapered hole in a thick walled, restricted section of the filler neck
11 that is transverse to the gas filling path and intersects it. An extrudable material is
12 held in the transverse tapered section to provide the 'working' seal. When the
13 permanent seal is to be made, the transversely held material is extruded into the filling
14 path using a side force. Both the side and end openings may then be electron beam
15 welded to form the long term permanent seal. Once the reactor is sealed, it must be
16 stored at a suitable temperature that is well below the threshold temperature to ensure
17 that the fusion reaction is not accidentally enabled. (See the later section on How the
18 reactor works.)

19 20 **The reactor body:**

21
22 In the preferred embodiment, the reactor pressure vessel body is made from a
23 suitable high-strength, high-temperature metal or alloy which has one or more of the
24 following properties: (1) impervious to hydrogen, (2) is not subject to hydrogen
25 embrittlement and/or (3) is coated on the inside with a material such as beryllium-
26 bronze which is impervious to hydrogen and its isotopes. The optimum diameter of
27 the reactor pressure vessel and the thickness of the material used to form the
28 pressure vessel body are determined by stress and strength analysis to suit the
29 operating conditions.

30 Generally, it is the application requirements that will set the design operating
31 temperature; the materials and dimensions for the reactor body must be appropriately
32 selected. In Fig. 7, the operable temperature range is from 400°C to more than
33 1400°C.

34 In the lower to mid-range operating temperatures of 400°C to 1000°C,

1 materials for the pressure vessel body may be selected from a group of alloys used in
2 the manufacture of jet engine turbine blades and in other high temperature uses.
3 ~~Other materials may suit reactor conditions which are less demanding. One such~~
4 material is Carpenter's Pyromet Alloy 680 which is ideal for the 400°C to 1000°C
5 range and is inexpensive and easy to machine.

6 For the higher temperatures in the 1000°C to 1400°C range, a material such as
7 pure tungsten may be used. The operating range shown in Fig. 7 is applicable when
8 the host metal is a metal such as palladium with a melting temperature in the 1500°C
9 range.

10 When using tungsten for the reactor body, the operating range of temperatures
11 noted in Fig. 7 may be extended up to 3000°C for use with a host metal having a high
12 melting temperature. Also, when using tungsten for the reactor body, the range of
13 operating deuterium chemical potentials may be extended into the 60kJ/mol range.
14

15 **The host metal:**

16

17 In the preferred embodiment, palladium is the host metal. Other candidate host
18 metals may be selected from a group consisting of: titanium, zirconium, vanadium,
19 thorium, lanthanum, praseodymium, tantalum, uranium, hafnium, nickel and cerium.
20 The host material may also be an alloy, or mixture, of the selected metal with one or
21 more other elements. ~~Suitable~~ Candidate host metal forms include wire, plate, foil,
22 powdered and deposited forms. **[Paragraphs** *"The design thickness of the host metal*
23 *will vary from a fraction of a millimeter to several millimeters depending upon the host*
24 *material selected and the required surface power density. The length, or overall size*
25 *of the reactor is a function of the total power required."* and *"In the preferred*
26 *embodiment, the host metal is affixed to the inside surface of the reactor so that heat*
27 *flow from the host metal to the heat transfer surfaces is enhanced. Other designs may*
28 *place the host metal at other locations inside the reactor. Candidate processes for*
29 *installation of the host metal include: various deposition processes and other solid*
30 *forms, which may be on a sub-strait and otherwise fixed in place, and powdered forms*
31 *sintered in place or otherwise confined. The host metal is cleaned after installation to*
32 *remove surface contamination and facilitate the dissolution of deuterium."* **have been**
33 **moved to later section: "Host Metal Installation". The final selection of the host metals**
34 **is described in a later section, Host Metal Selection.]**

1

2 **The reactant gas:**

3

4 In the preferred embodiment, the reactant gas is deuterium, D_2 . ~~Some small amount~~
5 ~~of other gasses or other materials may also be mixed with the deuterium reactant gas.~~

6

7 **How the reactor works:**

8

9 The objective of the method described in this section is to enable and
10 accelerate the heat producing reaction for the purpose of producing high density heat.
11 Following this method will create and exceed the system free energy states indicated
12 in the experimental evidence presented in Fig. 9.

13 ~~The Presurized deuterium is dissolved in the host metal by confining the~~
14 ~~deuterium gas virtue of its being in contact with the surface of the host metal. The~~
15 ~~amount of deuterium that dissolves per unit of host material is a function of (1) the~~
16 ~~temperature of the host metal and (2) the pressure of the deuterium gas. The~~
17 ~~concentration of deuterium in the host metal is given by the temperature,~~
18 ~~concentration and pressure. D-Pd TCP Equilibrium Diagram for the gas-metal system~~
19 ~~as shown in Fig. 8.~~

20 At the high temperatures where the system is operative and high density heat
21 is being produced, Fig. 9, the D/Pd concentrations will be low as indicated on the
22 Equilibrium Diagram. There is no finite minimum D/Pd concentration required for
23 operation; only that some deuterium be present.

24 The heat producing reaction is enabled by raising the thermodynamic system
25 free energy state, corresponding to the deuterium gas chemical potential, of the gas-
26 metal system to its critical reactive threshold level, where At the threshold level, the
27 'dissolved' deuterium undergoes a change of state, seeking its lowest possible free
28 energy. It is this change of state that nullifies the Coulomb repulsion forces and
29 enables the fusion reaction. The chemical potential of the 'dissolved' deuterium, at
30 equilibrium, is uniform throughout the host metal and it is a function of the deuterium
31 'gas' chemical potential at the surface of the host metal. The 'gas' chemical potential
32 can be measured and controlled by controlling the D gas pressure and the reactor
33 temperature. The threshold of the heat producing reaction is the deuterium 'gas'
34 chemical potential that produces the critical 'dissolved' deuterium chemical potential

1 that is critical to its change of state. The relationship between the gas chemical
2 potential and the chemical potential of the dissolved deuterium is explained in
3 Technical Note TN-7.1, Reference 5, and is shown explicitly in equations (h), (i) and (j)
4 of that document. The heat-producing reaction is spontaneous once it is enabled.
5 The rate of the heat production is increased as the operating chemical potential is
6 raised above the threshold.

7 For the sealed reactor, only the temperature can be controlled directly and the
8 pressure for any given temperature is a function of that temperature. The pressure
9 and the associated D chemical potential may be predicted for any given temperature
10 knowing the ratio of the 'free-gas-volume' to the 'palladium volume' installed in the
11 reactor as described in the later section. Predicting the performance of sealed
12 reactors.

14 **Chemical potential:**

16 In the present invention, the term 'D chemical potential' is used as a measure of
17 the free energy state of the system. The term 'chemical potential', when used for a
18 gas-metal system, is defined as the change in Gibbs Free Energy, in Joules per mol,
19 that would be required to force one more mol of a gas into a large gas/metal system,
20 at its present free energy state, while holding the temperature, pressure and the
21 concentration of other species constant. The chemical potential, μ , of the deuterium
22 gas is given by the equation:

23
$$\mu = (0.5RT) \log_n(P/P_0) \quad \text{(Equation 1)}$$

24 where: μ is the gas chemical potential (J/mol). R is the gas constant (8.32
25 Joules/mol°K), T is the temperature in Kelvin, P is the deuterium gas pressure in
26 atmospheres and P_0 is the selected standard state pressure of 1 atmosphere. Since
27 the chemical potential of the dissolved deuterium is a function of the gas chemical
28 potential, it also is a function of the two control variables, T and P.

30 **Host metal selection:**

32 The threshold deuterium gas chemical potential may be different for each
33 candidate host material vary from one candidate host material lot to another. The

1 threshold chemical potential ~~of the~~ for a specific host material is also dependent on
2 the system's electronic Fermi energy as well as other factors including the purity,
3 crystal size and regularity, and the population of flaws, cracks, vacancies, distortions
4 and dislocations in the crystal lattice structure of a particular host material. Some of
5 these micro-properties might be altered in the process of installing the host inside of
6 the reactor.

7 Because of this variation in micro-properties, each lot of the candidate metals is
8 subjected to screening tests, in their final form, to determine their threshold deuterium
9 gas chemical potentials. Such screening tests and measurement of the threshold
10 chemical potential are conducted for any candidate host metal in a ~~The threshold~~
11 ~~deuterium gas chemical potential may be measured for any candidate host material in~~
12 a properly instrumented pressure vessel. The material-form combinations with the
13 lowest threshold chemical potentials are the best candidates. The final selection of a
14 metal and form will be dictated by the application requirements.

15 The 'instrumented' pressure vessel for screening the candidate host materials
16 is called a 'scanning' reactor with means for temperature and deuterium gas pressure
17 control. For the scanning reactor to be an effective tool for the process of selecting the
18 host metal and form, it is designed for a broad operating range in terms of high D
19 chemical potentials, high temperatures and high pressures. When the reactor body is
20 made from pure tungsten, D chemical potentials up to the range of 70 kJ/mol,
21 operating temperatures up to about 3000°C and D gas pressures up to the range of
22 4000 atmospheres can be achieved.

23 A typical general arrangement of the scanning reactor and typical test samples
24 are shown in Fig. 6.

- 25 • The scanning reactor body 41 is designed to minimize heat conduction to its
26 attachment base and to minimize heat radiation to its surroundings. By
27 operating in the vacuum provided by the vacuum chamber 44, the losses
28 by convection are eliminated. The sensitivity of threshold measurements
29 and the accuracy of heat rate measurements depend on how well the
30 reactor is isolated. The material for fabrication of the reactor body 41
31 should be selected from the group of candidates for the production reactor
32 noted in the previous section. The reactor body.
- 33 • The heater coil 42 is the means to control the temperature of the test sample.
- 34 • The base of the vacuum chamber 44 incorporates the D₂ gas pipe

connections 46 for the scanning reactor and the external piping. The base also incorporates the electric wire feed-thru 45 and the vacuum port 48.

- The cross fitting 47 permits ready through access to the reactor body for the test sample assembly 55 facilitating rapid change of test samples with just a single high pressure disconnect. It 47 also provides side ports for the high pressure D₂ gas from the gas supply system 51 and access to the vacuum system 52. The D₂ gas pressure gage 50 provides the necessary pressure data for calculating chemical potentials.

- The test sample assembly 55 consists of a substrate 56 and the host metal sample 57. The host metal sample 57 is processed onto the substrate using the installation process planned for the production reactor.

- The thermocouple 43 is the reference measurement for detection of the onset of fusion heating by the thermocouple 54 on the temperature probe 53. When the system is at thermal equilibrium and the fusion reaction is not yet enabled, the two thermocouples 43 and 54 will read alike. When the onset of the fusion reaction is reached, the thermocouple 54 on the probe will read higher than than the thermocouple 43 on the reactor body. The temperature rise (54 minus 43) due to the onset of 'fusion' heating is one that persists beyond the transient heats due to dissociation, ionization, solution and lattice transformation.

Measurement of the threshold D chemical potential is accomplished by recording the reactor body temperature 43 and gas pressure 50 at the onset of the heat producing reaction when a temperature rise 53 of the test sample above the surroundings is detected. The threshold chemical potential is then calculated from the Equation 1 noted above using that temperature 43 and pressure 50 recorded at the onset.

Once the threshold D chemical potential is measured for particular sample, there is a family of temperature and pressure combinations that will produce that same D chemical potential that now may be used in design as the minimum operating conditions to enable the fusion reaction.

The scanning reactor is also used to measure the heat production rates over the range of operating temperatures specified for the application. For the scanning reactor to be effective for measuring rates, it must also incorporate calorimetry. One direct measurement method is by noting the reduction of control heater 42 power to

1 maintain constant temperature 43 when the test sample 57 is producing heat. For this
2 method of calorimetry, all heat losses must be minimized. To make these rate
3 measurements, the installed volume of the host metal sample 57 is adjusted so that
4 the heat generated at the test operating conditions is approximately equal to the mid-
5 range of heat produced by the heater 42. Knowing the heat necessary to make up the
6 losses in the system at the test temperature, the heater power may be reduced from its
7 'loss maintenance' rate to compensate for the heat generated by the test sample,
8 thereby maintaining a constant temperature and giving a direct reading of the heat
9 generated.

10 Knowing the volume or weight of host metal in the test sample, the average
11 power density may be readily calculated, in watts per cubic centimeter, for each level
12 of operating chemical potential applied. It is this heat production rate characteristic of
13 the host metal that will permit determination of the thickness of the host metal to be
14 used for a particular application.

15 The scanning reactor is also used to determine the slope of the heat generation
16 rate curve at the design operating temperature so that the heat transfer system may be
17 designed for stability. The slope of the heat transfer characteristic curve at the
18 operating conditions must be greater than the slope of the power production curve at
19 that point for there to be a stable operating temperature. Determining the slope of the
20 sample's characteristic heat production curve is accomplished by measuring the heat
21 generation rate over a range of temperatures above and below the design operating
22 temperature and plotting the data for analysis.

23

24 **Host metal installation:**

25

26 In the preferred embodiment, the host metal is affixed to the inside surface of
27 the reactor so that heat flow from the host metal to the heat transfer surfaces is
28 enhanced. Other designs may place the host metal at other locations inside the
29 reactor. This is illustrated in Figure 4 where the heat transfer surface is along the
30 central heat transfer fluid tube 36. ~~Candidate processes for installation of the host~~
31 ~~metal include: various deposition processes and other solid forms, which may be on a~~
32 ~~sub-strait and otherwise fixed in place, and powdered forms sintered in place or~~
33 ~~otherwise confined.~~

34 Candidate methods for installation of the host metal include: (1) various

1 deposition processes, (2) other solid forms, which may be on a substrate, and (3)
2 powdered forms sintered in place, or otherwise confined. Some candidate methods
3 of installing the host metal are briefly described here:

4 (1) Fabricate the host metal in the form of a tube in the metal-producing mill by
5 standard techniques of casting, and a series of "drawing" steps with
6 intermediate anneals. This is a "bulk" technique. The dimensions of the
7 host metal tube are such that the outside is a close fit to the inside of the
8 reactor body. The outside surface of the host metal tube may be coated
9 with brazing material. After insertion, a mandril may be inserted to
10 expand the host tube to an "interference" fit. The assembly is then
11 heated to the brazing temperature to produce a strong and conductive
12 interface.

13 (2) Another method employs the use of host metal in a powdered form,
14 available commercially, which is placed into position so the powder
15 tightly fills a tubular space inside the pressure vessel, kept in place by a
16 mandril. The assembly is then heated to the sintering temperature,
17 which produces inter-diffusion of host metal powder particles so they
18 become firmly attached to each other and to the inside surface of the
19 reactor body. The mandrel is then removed.

20 (3) Still another method is to use a vapor-deposition technique in which a
21 vapor of host metal is produced in an evacuated space and is deposited
22 in a layer on the inside surface of the reactor body.

23 The host metal is cleaned after installation to remove surface contamination
24 and facilitate the dissolution of deuterium.

25 The design thickness of the host metal will vary from a fraction of a millimeter to
26 several millimeters depending upon the host material selected, its measured heat
27 production rates over the operating temperature range and the required surface
28 power density, or heat flux, specified for the application. The length, or overall size of
29 the reactor is a function of the total power required.

30 The present invention is operable with any one of many installation methods.
31 In each case, the threshold D chemical potential and the power production
32 characteristics are determined by 'scanning' tests for the specific combination of host
33 metal and installation process to complete the design.

34

1 **System control.**

2

3 Heat production rate stability is preserved by maintaining a constant host metal
4 temperature for a given deuterium gas pressure. This is accomplished by ensuring
5 that the heat transfer rate away from the reactor is equal to the heat generation rate.
6 Since the reaction heat rate is an exponential function of temperature, positive
7 temperature feedback and 'run-away' may occur if the heat transfer rate is
8 inadequate.

9 When heat transfer is by forced convection, the host temperature, for a given
10 deuterium gas pressure, is controlled by controlling the temperature and the flow rate
11 of the heat transfer fluid as seen in Fig. 5.

12 When heat transfer is by radiation, with a high operating temperature for the
13 reactor and a low receiver temperature, the heat transfer rate is essentially a fourth
14 power function of absolute temperature of the reactor. In general, if the reactor heat
15 generating rate, being an exponential function of temperature, is less than a fourth
16 power function of temperature, then the reactor will be stable at the design operating
17 temperature. If the heat generation rate is greater than a fourth power function of
18 absolute temperature, then supplemental convection cooling of the reactor may be
19 required to maintain stability.

20

21 **Control of the sealed reactor.**

22

23 Startup and control of the sealed reactor is accomplished by controlling only
24 the temperature of the reactor.

25 The performance of a sealed reactor is determined the same way as that for a
26 pressure controlled reactor; the fusion reaction is enabled by producing the threshold
27 chemical potential measured for the host metal in the scanning reactor. The rate of
28 the reaction is increased by increasing the operating D chemical potential over the
29 threshold. The difference for the sealed reactor is that the internal D gas pressure
30 cannot be changed independently or even measured easily. It can, however, be
31 predicted and the D chemical potentials can then be calculated for any given
32 temperature.

33 By predicting the internal pressures and calculating D chemical potentials over
34 the operating temperature range, the threshold temperature and the heat generation

1 rates of the reactor at various temperatures above the threshold can be calculated.

2

3 **Predicting the performance of sealed reactors:**

4

5 When the reactor is operating in the sealed condition, the internal reactor
6 pressure, at any given temperature and gas volume, is dependent on (1) the mass of
7 the deuterium in the host metal and in the void volume at the time of sealing, and (2)
8 the ratio of the 'void-volume' to the 'host-metal-volume' inside the reactor. The
9 pressure is controlled by controlling the reactor temperature.

10 To predict the pressure for any given temperature, it is necessary to first
11 determine the total number of mols of deuterium that were 'installed' at the time of
12 sealing. To determine the number of mols of deuterium in the host metal, the total
13 number of mols of host metal installed inside the reactor must be known and the
14 reactor temperature and gas pressure at the time of sealing must have been
15 measured. The number of mols of dissolved deuterium within the host metal is then
16 determined using concentration data from the TCP Equilibrium Diagram. The
17 number of mols of deuterium in the void volume, n_v , is calculated using the ideal gas
18 law, $PV=nRT$. The sum of the two numbers will remain the same once the reactor is
19 sealed, but, as temperature is increased, some of the dissolved deuterium in the metal
20 will be driven into the void volume thereby amplifying the pressure increase that
21 would have occurred had there been no change in the concentration of deuterium in
22 the host metal. At the higher temperature, a new equilibrium will be reached at a
23 higher pressure in the void volume and, in turn, will further increase the operating
24 chemical potential. The amplification factor is a function of the ratio of 'void-volume'
25 to 'host-metal-volume'. This ratio may be adjusted in design by adding an inert filler
26 material to the void space.

27 When the void volume is large relative to the host-metal volume, the pressure
28 amplification due to deuterium expulsion from the host metal with a rise in
29 temperature is small. When an inert filler material is used to significantly reduce the
30 void volume, the pressure amplification as a result of deuterium expulsion from the
31 host metal may be made very large (in the range of 100 times and more) depending
32 on how much the void volume is reduced by the filler. The preferred material for the
33 inert filler material is one which is relatively impervious to hydrogen. The filler
34 material may be a solid core or a closely packed loose material. Quartz or alumina is

1 are a candidates for the filler material.

2

3 **Useful life of the sealed reactor:**

4

5 The useful life of the reactor 1, when operating sealed, is limited since
6 deuterium is depleted in the reaction. As deuterium is converted to helium, the partial
7 pressure of the deuterium in the void space will decrease and the partial pressure of
8 the helium will increase. This decrease in the partial pressure of the deuterium will
9 have the effect of reducing the operating D chemical potential and hence the rate of
10 the fusion reaction. When the application requires that the heat generation rate
11 remain constant, then it will be necessary to compensate for the drop in pressure by
12 operating the reactor at a correspondingly higher temperature to maintain the same
13 operating D chemical potential. In convective heat transfer, this is accomplished by
14 decreasing the heat transfer rate. This action will cause the temperature to rise and
15 the correct operating D chemical potential to be restored. When the operating heat
16 generation rate is restored at a higher temperature, then the heat transfer rate may
17 require readjustment so that it is equal to the restored heat production rate.

18 In this case, the useful life of the sealed reactor is limited to how much
19 adjustment in operating temperature can be made before the maximum temperature
20 allowable for that particular reactor body design and material is reached.

21 When the application can tolerate a drop in the heat generation rate, then the
22 useful life of the sealed reactor is limited to the time to reach the minimum heat
23 generation rate that meets the minimum application requirements.

24

25 **The Operating System:**

26

27 A given reactor operating system is designed to fit the application requirements
28 in terms of the operating conditions and the method of heat transfer. As a minimum,
29 the control system must incorporate: (1) a means to load the deuterium into the reactor
30 and host metal, (2) a means of controlling the chemical potential of the dissolved
31 deuterium, (3) a means of extracting all of the generated heat and thereby providing a
32 means of controlling the temperature of the host metal.

33

34 **Loading the Reactor:**

1

2 Referring to *Fig. 3*, the deuterium gas pressurization system consists of a gas
3 storage system 9, pressurization pumps 10, vacuum pumps 11, isolation valves 12, a
4 high pressure manifold 13 to interconnect the components and to connect the system
5 to the reactor assembly 1. The pressure in the manifold is indicated by pressure gage
6 14 which may include an electronic pressure signal to the operating control panel 27.
7 The gas storage system 9 may include filters, traps, regulators, etc.

8 The reactor 1, the manifold 13, the pressurizing equipment 10, the gas storage
9 equipment 9 and associated lines are evacuated through the isolation valves 12
10 using the vacuum pumps 11 to remove contaminating gases. When the enabling
11 heater 34 (in Fig. 1 & 2) is not integrated into the heat transfer surfaces, then the
12 operating chamber 15 heater 17 may be operated to raise the temperature of the
13 reactor to a value in the 600 to 800°C range for an extended period of time while
14 under vacuum to remove residual contamination from the reactor and host metal.
15

16 **Typical loading procedures:**

17

18 In the preferred loading method, the temperature of the reactor 1 and the
19 operating chamber 15 is raised above ~~300~~ 400°C while still under vacuum using the
20 enabling heater 34 (Fig. 1 & 2) or heater 17 (Fig. 5). The heat transfer fluid pump 20 is
21 off during the loading procedure. The isolation valves 12 are closed and the
22 deuterium gas supply valve and regulator 9 are opened. The deuterium gas is
23 pumped into the high pressure manifold 13 and reactor 1 using the pressurization
24 equipment 10 controlled from the control panel 27 and is indicated on the manifold
25 pressure gage 14. The gas pressure is raised to that value necessary, at the loading
26 temperature 8, to achieve the threshold chemical potential for heat generation. At this
27 operating point, the reactor 1 is ready for operation as a heat generator. When the
28 threshold chemical potential cannot be reached at the selected loading temperature,
29 then a higher loading temperature must be used. An alternative is to load at the lower
30 temperature and then raise the temperature until the threshold is reached.

31 When the reactor is to be used as a sealed reactor, it is loaded with deuterium
32 to a predetermined temperature and pressure and then sealed. The final loading
33 temperature and pressure at sealing are selected so that the deuterium gas pressure
34 inside the reactor will reach the correct pressure at the design operating temperature

1 to produce the required chemical potential which, in turn, produces the desired heat
2 generating rate.

3 After ~~permanently~~ sealing, the a reactor, may be removed from the
4 pressurization system and stored for later use as a heat generator. Controlled low
5 temperature storage may be required to ensure that the threshold chemical potential
6 is not accidentally reached.

7

8 **System operation:**

9

10 Referring to *Fig. 3 5* the operating chamber 15 consists of: insulation 16 on the
11 outside, a heater 17 on the inside (or other means of heating the reactor for start-up),
12 a heat transfer fluid distribution system 18 which ensures that virtually all of the fluid
13 impinges on the reactor's heat transfer surfaces, an inlet temperature thermocouple
14 28 for control of the fluid temperature as it begins circulation over the reactor surfaces.
15 A calorimetry system 30 utilizes inlet and outlet thermocouples 32 & 33 and the heat
16 transfer fluid mass flow meter 31 to determine the heat generation rate.

17 The heat transfer system utilizes a heat transfer fluid, circulating in lines 19, 23
18 and 25, which may be a gas or a liquid to suit the application, and consists of: the
19 circulation pump 20, mixing valve 22 for controlling the temperature of the heat
20 transfer fluid 28 at the inlet of the operating chamber 15, the cooling heat exchanger
21 24 and cooling line 25 which supplies cooler fluid to the mixing valve 22, a heating
22 by-pass line 23 which provides hotter fluid to the mixing valve 22, flow rate control
23 valve 26 to provide heat production stability control by ensuring that the heat
24 transferred out is equal to the heat generated in the reactor, and the mass flow meter
25 31 which provides data required for calorimetry 30. The loads 21 and heat rejection
26 devices 24 remove the generated heat. The flow rate control valve 26 may be
27 eliminated if the pump 20 has a flow-rate control feature built into the pump.

28 Before operating the system, the operating chamber 15 and all of the heat
29 transfer fluid components, including the heat-using devices 21, are purged of all
30 unwanted fluids and the selected heat transfer fluid with a known specific heat is
31 introduced.

32

33 **Typical Operation at the Desired Power Production Rate**

34

1 Once (1) the reactor 1 and the heat transfer system have been brought up to
2 the design operating temperature range 8, (2) the deuterium gas pressure 14 has
3 been increased so that the threshold of heat production has been surpassed and (3)
4 the reactor heat generation rate exceeds the system loss rate, the heater 17 (or the
5 enabling heater 34) may be turned off. The host metal temperature is now under
6 control of the heat transfer system. It is controlled by adjusting (1) the mixing valve 22
7 position to provide heating 23 or cooling 24 & 25 of the heat transfer fluid after heat is
8 extracted by the loads, and (2) the heat transfer fluid flow rate control valve 26.

9 The average power production rate is controlled by controlling the reactor
10 temperature 8, as noted, and the deuterium gas pressure 14 so that load demands 21
11 are met with the mixing valve 22 in approximately the center position. Short-term
12 changes in load demand are met by adjustments in the heat transfer fluid temperature
13 28 and flow rate 26. Reactor stability control takes priority over load demand.

14 When the reactor is operating sealed, the power production rate is modulated
15 by adjusting the operating temperature 8. As the deuterium is depleted, the power
16 production rate for a given temperature will decrease. To compensate, the reactor is
17 operated at gradually higher temperatures over the life of the reactor. This is
18 accomplished by adjusting the flow rate control vale 26. A reduced flow will increase
19 the operating temperature and an increased flow will reduce the operating
20 temperature. After any adjustments in temperature, it is necessary to restore the heat
21 transfer rate to be equal to the generation rate for stability.

22 With the reactor is operating unsealed, it, and its operating system, will require
23 periodic maintenance to remove the product of the reaction, helium. When the reactor
24 is operating sealed, it will require periodic recycling to remove the product of the
25 reaction.

26

27

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1 ~~What is claimed is:~~ **We Claim:**

2

3 ~~1. A system for generating heat from deuterium comprising:—~~

4 ~~• a pressure vessel reactor; said reactor having a void space;—~~

5 ~~• a host metal; said host metal distributed inside said reactor;—~~

6 ~~• a reactant gas, deuterium, within said reactor void space and dissolved in said~~
7 ~~host metal; said heat generation from the dissolved deuterium dependent~~

8 ~~on the deuterium gas pressure and the reactor temperature;—~~

9 ~~• means of controlling said reactor temperature and said deuterium gas pressure;—~~

10 ~~• means of controlling said reactor temperature by controlling the rate of heat~~
11 ~~extraction;—~~

12 1. A system for generating solid state deuterium fusion heat at elevated system free
13 energy states, corresponding to high deuterium chemical potentials, comprising:

14 • a pressure vessel reactor; said reactor having a void space; said void space
15 containing a host metal and deuterium gas; said deuterium gas at
16 elevated pressure within said reactor void space and dissolved in said
17 host metal;

18 • a means of providing a vacuum in said reactor before said deuterium is
19 introduced;

20 • means of controlling said reactor's temperature and said deuterium gas
21 pressure;

22 • means of transferring the generated heat to a useful load.

23 ~~2. A system as set forth in claim 1, wherein said host metal inside said reactor is one~~
24 ~~taken from the group consisting of: palladium, titanium, zirconium, vanadium, thorium,~~
25 ~~lanthanum, praseodymium, tantalum, uranium, hafnium, nickel and cerium.—~~

26

27 ~~3. A system as set forth in claim 1, also comprising a means of sealing said pressure~~
28 ~~vessel after introducing said deuterium; said deuterium gas pressure, after sealing,~~
29 ~~being dependent upon the reactor temperature;—~~

30 3. The system of in claim 1, comprising:

31 • a means of permanently sealing said pressure vessel after introducing said
32 deuterium.

33 ~~4. A system as set forth in claim 3, also comprising inert filler material inside said~~
34 ~~pressure vessel to reduce the void space; said reduction in void space causing an~~

1 ~~amplification of said deuterium gas pressure increase when said reactor temperature~~
2 ~~is increased.~~

3 4. The system of claim 3, comprising:

- 4 • inert filler material inside said pressure vessel to reduce said void space; said
5 reduction in void space enhancing the deuterium gas pressure increase
6 as the reactor temperature is increased.

7 5. The system of claim 1, wherein said host metal is palladium.

8 6. The system of claim 1, wherein said host metal is titanium.

9 7. The system of claim 1, wherein said host metal is nickel.

10 8. The system of claim 1, wherein said host metal is zirconium.

11 9. The system of claim 1, wherein said host metal is vanadium.

12 10. The system of claim 1, wherein said host metal is thorium.

13 11. The system of claim 1, wherein said host metal is lanthanum.

14 12. The system of claim 1, wherein said host metal is praseodymium.

15 13. The system of claim 1, wherein said host metal is tantalum.

16 14. The system of claim 1, wherein said host metal is uranium.

17 15. The system of claim 1, wherein said host metal is hafnium.

18 16. The system of claim 1, wherein said host metal is cerium.

19 ~~17. A system of claim 1, wherein said host metal inside said reactor is in a deposited~~
20 ~~form.~~

21 18. The system of claim 1, wherein said host metal is in a powdered form.

22 19. The system of claim 1, wherein said host metal is in a solid form.

23 20. Using the system of claim 1, comprising:

- 24 • a method in which deuterium gas chemical potentials in the range of 15 kJ/mol
25 to 50 kJ/mol are produced at temperatures ranging from 400°C to 1500°C
26 and at deuterium gas pressures ranging from 25 atmospheres to 2,000
27 atmospheres.

28 21. Using the system of claim 3, comprising:

- 29 • a method in which deuterium gas chemical potentials in the range of 15 kJ/mol
30 to 50 kJ/mol are produced at temperatures ranging from 400°C to 1500°C
31 and at deuterium gas pressures ranging from 25 atmospheres to 2,000
32 atmospheres.

33 22. A system for testing candidate host metals to determine their threshold deuterium
34 gas chemical potentials and heat production rates comprising:

- 1 • a pressure vessel reactor; said reactor for containing said candidate host metal
- 2 and deuterium gas under pressure;
- 3 • a heater surrounding said reactor;
- 4 • a means of providing a vacuum in said reactor before said deuterium is
- 5 introduced;
- 6 • a system design that minimizes heat transfer away from said candidate host
- 7 metal and heat transfer away from said reactor;
- 8 • a probe for supporting said host metal in said reactor;
- 9 • a temperature sensor in the end of said probe;
- 10 • means of measuring said deuterium gas pressure and said reactor
- 11 temperature;
- 12 • means of controlling said reactor temperature and said deuterium gas
- 13 pressure;
- 14 • a means of measuring the heat generation rate within said host metal.

15 23. Using the system of claim 22, comprising:

- 16 • a method in which said deuterium gas chemical potentials in the range of
- 17 15kJ/mol to 75kJ/mol are produced at temperatures ranging from 400°C to
- 18 3000°C and at deuterium gas pressures ranging from 5 atmospheres to
- 19 4000 atmospheres.

20 24. Using the system of claim 22, comprising:

- 21 • a method in which the said threshold deuterium gas chemical potential at the
- 22 onset of heat generation is determined for said candidate host metal.

23 25. Using the system of claim 22, comprising:

- 24 • a method in which said heat generation rates are determined for said
- 25 candidate host metal.

26 26. Using the system of claim 1, comprising:

- 27 • a method of said heat generation by providing said deuterium chemical
- 28 potentials in excess of measured threshold deuterium chemical potentials
- 29 for said host metal.

30 27. Using the system of claim 3, comprising:

- 31 • a method of said heat generation by providing said deuterium chemical
- 32 potentials in excess of measured threshold deuterium chemical potentials
- 33 for said host metal.

Abstract

~~The deuterium heat generator is a pressure vessel reactor containing deuterium gas and a metal, such as palladium, having a crystal lattice structure capable of hosting a deuterium heat-producing reaction. The deuterium is dissolved in the host metal and its chemical potential is raised until the heat-producing reaction is enabled. The controls for the reaction are (1) the deuterium gas pressure and (2) the reactor temperature. The reactor temperature and the stability of the reaction is controlled by controlling the heat extraction rate. When the reactor is sealed after loading deuterium, it may be stored and then operated separate from its pressurizing equipment. The heat-producing reaction is self-sustaining, once started.~~

This invention is a reactor and system with a method for containing and controlling a deuterium nuclear fusion reaction in a palladium host metal lattice, now generally referred to as 'solid state fusion'. The reactor is designed for high temperature operation at moderate deuterium gas pressures and is operable over a temperature range of 400°C to more than 1400°C. The solid state fusion reaction is enabled and controlled by providing specific combinations of reactor temperatures and deuterium gas pressures. The invention is capable of generating heat densities that are suitable for commercial applications. The highest heat densities are produced at higher temperatures and moderate pressures where the system is most efficient and cost effective.